

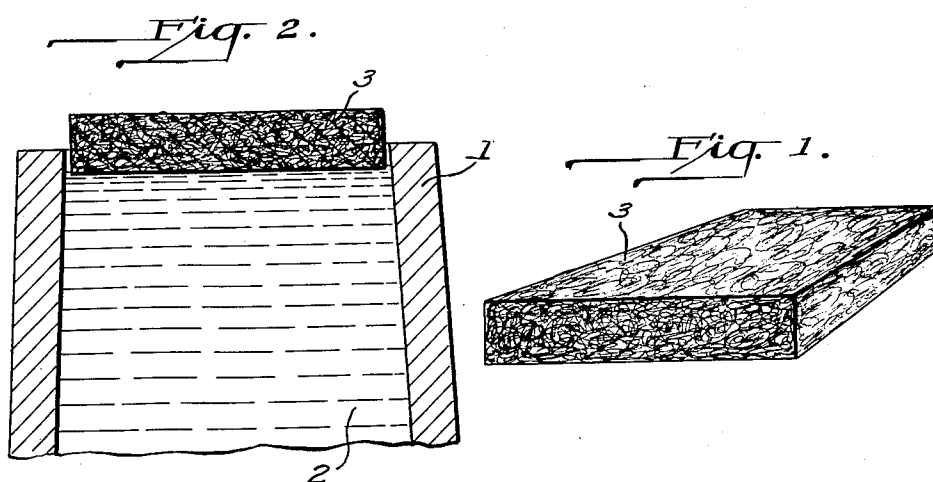
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CASTING METALS

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WITNESSES

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CASTING METALS

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This invention relates to the casting of metal, particularly to the casting of ingots for working, as by rolling or forging.

It is among the chief objects of the invention to provide improvements in such casting operations whereby to effect not only recovery of greater proportions of usable or salable material from the ingot than have been recovered in prior practice, but also to minimize difficulties and defects arising in prior practice, and to effect substantial economies in casting costs.

More particularly, a major object of the invention is to provide a method of casting ingots which is cheap and easily practiced, and does not require fragile and expensive hot tops, or sink heads, of the types now commonly used, and which minimizes piping and blow hole formation in the ingot and avoids the formation of hanger cracks.

A further object is to provide means for use in the practice of such a process which are cheap, easily handled, and not fragile, and which cooperate to reduce piping and blow hole formation to a minimum with resultant recovery of high proportion of salable product.

In the casting of metals for rolling or forging, and especially in the making of steel ingots, to which the invention is particularly applicable, a prerequisite is the provision of ingots as free as possible from defects, particularly piping and blow holes. The mechanism of the formation of these defects is well understood and requires no particular elucidation here. Likewise, the disadvantages of piping and blow holes are well recognized in the art. Thus, a piped portion of an ingot represents waste material since it can not be converted into salable finished product, and blow holes may be disadvantageous either because the porous metal does not weld, or because they cause the formation of slivers and other surface defects in the finished material.

The formation of pipes in steel ingots has been combatted in various ways all of which, so far as I am aware, aim to maintain the metal at the top of the ingot molten for a period of time sufficient to permit solidification without the formation of a pipe, or with formation of only a small pipe confined to the end of the ingot.

The common practice is to apply to the top of the mould a so-called hot top, or sink head casting, which, as is well known, is a tubular member which constitutes an extension of the mould. Two general types of hot top have been used. The first of these is made from refractory ceramic material, such as fire clay, and the second com-

prises a metallic shell lined with refractory material. The refractory type is disadvantageous because the hot tops are heavy, fragile, and subject to high breakage losses, and they can be used for the pouring of but one ingot. The lined type generally can be used in the production of more than one ingot, but their initial cost is high.

These hot tops have been widely used but they possess a number of undesirable characteristics. Thus, they are fragile, heavy and clumsy, and they require handling by a crane, at least the larger sizes. A substantial amount of manual labor is necessary in their use. Inevitably a material portion of the ingot must be cropped off, and the hot top residues may damage the soaking pits. These and other factors combined to render the costs of hot topping by sink heads rather high, as will be discussed more in detail herein-after.

In addition, it has been proposed to make the sink head type of hot top from insulating materials or structures to conserve heat in that portion of the ingot.

Despite the numerous proposals for reducing piping and blow hole formation, and despite the experience gained from use of all types of hot tops in the casting of many millions of tons of steel, substantial losses of metal still accrue. Even with the best practice in the use of ceramic hot tops, which up to now have been considered generally to be the best means of reducing piping, large losses of metal result, and these losses increase, generally speaking, with the size of the ingot. Experience has shown that as much as 20 per cent or more of the weight of the ingot must be cropped; this represents the sink head portion of the ingot, which is an inevitable loss, and cropping to remove piping which has extended into the ingot body. Such croppage is loss because it can not be converted into salable finished product. In ordinary practice, the best recovery with any size of ingot is usually about 84 per cent, and as indicated, the losses may be, and commonly are, greater. In fact, the increase in yield using hot tops is so small in some instances that some steel producers consider that the cost of hot topping is not justified.

The invention will be described with reference to the accompanying drawing in which Fig. 1 is a perspective view of a slab used in this invention; and Fig. 2 a vertical sectional view of the upper end of an ingot mould showing the slab of Fig. 1 in use.

The present invention is predicated upon my discovery that piping may be reduced materially

or substantially eliminated by disposing in the mould opening, after the metal has been poured, a slab of sub-divided cellular material bonded with heat-resistant binder to provide a porous and heat-insulative structure. I have found that thereby the dissipation of heat from the upper end of the ingot is repressed to an extent such that, as compared with the best prior practice, piping is materially reduced and the recovery of useful material is substantially increased. In the practice of the invention as thus described the slab of material referred to is of substantially the same size as, but somewhat smaller than, the mould opening so that it rests directly on the upper surface of the ingot metal.

In the preferred embodiment of the invention there is used a slab of the foregoing type prepared by bonding coarse wood excelsior, or coarse wood shavings, with a heat-resisting cement. Wood shavings are particularly suitable because they provide a base material which is a poor conductor of heat, and because they can be formed into a slab having a low mass-to-volume ratio, thus providing a suitably porous structure having the heat-insulating characteristic from which flow the benefits of the invention.

Refractory magnesian cements, suitably a magnesium oxy-salt cement such as magnesium oxysulfate or magnesium oxychlorid, are suitable heat-resisting materials for bonding the shavings. The shavings are coated or impregnated, as by spraying them with or passing them through a bath of a suspension of burned magnesite in magnesium chloride or magnesium sulfate solution. For the best results the shavings should be covered completely with the cement, but a relatively thin coating suffices for the purposes of this invention. The treated shavings are then compressed to a desired degree, to provide porosity adequate to give high heat insulative properties while avoiding production of a too densely compressed mass. The pressed slab is dried, after which it is ready for use. This provides a porous slab which is hard, strong, of low mass-to-volume ratio, suitably heat insulating, and in which the wood fibers are encased in a thin coating of heat-resisting or refractory cement which also bonds the whole into a rigid and strong board, or slab.

As illustrative of a procedure suitable for the manufacture of slabs for use in the practice of the invention, air-dried logs are cut into 16 inch lengths which are then treated in a shaving machine to produce shavings 16 inches long, about $\frac{3}{16}$ inch wide, and about $\frac{1}{64}$ inch thick. These shavings are fed, suitably in the form of a mat, through a tank containing a bath of magnesium oxysulfate cement in the proportions of 50 pounds of magnesium oxide, suitably in the form of caustic magnesite, suspended in 75 pounds of a clear magnesium sulfate solution made by treating lightly calcined magnesium oxide with sulfuric acid.

On leaving the tank the shavings are passed between rolls to force out the excess oxysulfate cement, and they are then passed to a forming table. Slabs particularly suitable for the practice of the invention are formed by converting the treated shavings into a rectangular column which is then compressed to desired thickness. Thus, the shavings may be passed to a pressing table comprising four endless steel belts forming a rectangular section. The side belts may, for example, remain at a constant distance of 20 inches apart, and the top and bottom belts may

converge from an initial distance of 18 inches to a distance of 3 inches apart. This press table will accordingly first form the shavings into a 20 x 18 inch column which is converted into a board 20 inches wide and 3 inches thick.

From the forming table the board is passed through a drier in which it is dried at, for example, a maximum temperature of 600 to 700° F. The slab is then ready for use. Such material weighs about 6.6 pounds per square foot and is composed of approximately two-thirds cement and one-third wood fiber.

The material used in the practice of the invention provides a combination of properties which cooperate to materially improve ingot quality by reduction of losses, and to provide substantial economies as contrasted with prior practice. In the first place, the use of a porous slab having a low ratio of mass to volume, which characterizes the present invention, affords high heat insulation for the metal at the top of the mould since the slab absorbs and radiates to the outer atmosphere relatively little heat. This provides for maximum maintenance of molten metal at the top of the ingot which is necessary to achieve solidification with minimum pipe formation. Also, the retarded rate of freezing of the top of the ingot which follows the practice of my invention affords time for gas to escape from the solidifying metal, and as a result of the porous nature of the cover slab this gas escapes freely, thus minimizing blow hole formation also.

The practice of the present invention is exceedingly simple. Having reference to Figs. 1 and 2, the mould 1 is filled with metal 2, and when the mould has been filled a slab 3 of the type which characterizes the invention is placed in the mould opening to rest upon the surface of the metal.

This shows directly benefits which arise from this invention. Thus the slabs may be slid from the pouring platform into the mould opening so that the use of a crane is unnecessary. Since the moulds need no preparation, the ingot trains are run to the pouring platform, the heat poured at once, and the train moved out, whereby the platform is left free at all times for reception of the ingot train and immediate teeming.

Again, the formation of hanger cracks is entirely avoided in the practice of the invention and the expedients heretofore necessary in the use of hot tops to avoid their formation, such as the insertion under and removal of wedges from the sink head, are unnecessary and are eliminated.

In contrast with standard hot top practice, in the practice of the present invention the metal is poured successively into a series of moulds, the number being dependent upon the size of the mould, the quality of the steel, and similar factors, before any back pouring is necessary. This evidences the fact that in the practice of the present invention the metal is maintained adequately molten in the necessary region for longer periods of time than is possible with standard sink head hot top practice, and this is reflected in minimized pipe formation. In this way, as actual experience has shown, six, twelve or more ingots may be poured successively, as contrasted with the standard present practice of pouring two ingots followed by back pouring, and this results in a substantial saving of time, for example, ten to twenty minutes in the time needed to pour a heat.

Some of the most striking benefits appear upon consideration of sink head hot tops in compari-

son with the slabs used in this invention. A typical hot top of the sink head type for an ingot mould of common size, say having an opening 22 inches by 22 inches at the top, will be approximately 20 inches square and 18 inches high, with walls 2 inches thick. Its shipping weight is approximately 200 pounds, it occupies in shipment a space 4.2 cubic feet, and an ordinary car load will consist of about 440 such hot tops.

In contrast, a slab 11, Fig. 3, used with a mould of the same size will weigh, when made as described hereinabove, about 20 pounds. The slabs, 20 x 20 x 3 inches, will occupy but 0.7 cubic foot each, and they require practically no packing whatsoever in transportation. An ordinary car load will contain approximately 3600 pieces, and the danger of breakage in shipment is virtually nil. Even if a slab is broken it may be mended easily and cheaply by cement, which is not possible with fire clay hot tops. No special packing or wire banding is necessary, either before shipment or in use, so that not only is handling breakage no longer important, but also the danger of breakage in use, with its attendant hazard and disadvantages, is eliminated. The advantages arising from these features as contrasted with the sink head hot top will be obvious, particularly as to elimination of breakage losses and the ability to handle them without cranes and without great caution.

In further contrast, the hazards and difficulties arising from cracking and breakage of fire clay hot tops are eliminated by the present invention for all of the metal is contained within the mould as will be understood from what has been said. Hence there is no such danger as just described. Of especial importance is the fact that hanger cracks do not form in the practice of this invention, which increases yields because no metal need be shipped and no billets need be discarded because of such cracks. In addition to these economies, the high chipping costs are eliminated.

In the use of ordinary hot tops the clay refractory is shattered as the ingot is stripped from the mould, the refractory falling to the ground and accumulating so that it must be continually cleaned up, thus adding still another cost factor to hot top operation. In addition some amount of refractory almost invariably adheres to the sink head metal as the ingot goes to the soaking pits, and this is objectionable for two reasons. First, this refractory becomes fluxed by the iron scale in the heating of the ingot, producing a slag which is highly corrosive to the pit lining so that when this slag runs to the bottom of the pit it cuts out the refractory rather rapidly. It is a common experience, for instance, for a plant which has not been using hot tops to find that the soaking pit upkeep costs increase materially after hot top practice has been begun, because of this factor. This of course reflects itself in the steel costs and is directly attributable to hot top practice. In the second place, some refractory may remain adhering to the sink head when the ingot passes to the rolls. During blooming this refractory becomes dislodged, to mingle with the roll scale, and since the scale is usually returned to the open hearth or to the blast furnace, the refractory is objectionable because it constitutes a siliceous impurity. These items are completely eliminated in the practice of the present invention, there being left on the ingot no material which will flux with the scale and

affect the lining of the soaking pit, or which contaminates the roll scale, again illustrating the material benefits which flow from the invention in the reduction of casting costs.

In practically any size the slabs can be handled conveniently by one man without discomfort, there is no breakage in handling, and sufficient stock can be kept on the pouring platform for several days' requirements without tying up the labor crew for handling. The reduced storage space alone is often important in locations of this type.

As will appear to those skilled in the art, the foregoing features alone render the invention a substantial advance in the art, and their significance in expediting and simplifying ingot casting, and their effect upon costs require no detailed elucidation. The most substantial benefits arise, however, from increased yield of salable or usable metal, as will now appear.

Actual use of the invention in the casting of more than 100,000 tons of steel ingots in commercial practice in a large number of steel mills has shown that pipe formation and metal losses are so reduced that metal recoveries in killed steels in excess of 90 per cent are attainable in some instances as a result of the invention, as contrasted with an average of about 75 to 80 per cent in ordinary practice with or without sink head hot tops, and in all instances improvements of several per cent or more are obtained. In fact, at one plant alone more than 15,000 tons of steel ingots per month are being poured and treated in accordance with this invention.

This extensive experience in commercial practice of the invention demonstrates clearly the substantial benefits which arise not only from the economies flowing from reduced first costs and handling and allied costs, which will be understood from the foregoing discussion, but also from the increased yields of salable metal. For example, in the case of low carbon steel for sheet bar, it has been common not to hot top the ingots because steel producers have believed that the use of hot tops is not justified unless they materially increase the yield. Ordinary hot tops have not increased yields sufficiently with this class of steel to meet that requirement. The practice of the present invention in actual commercial practice on steel of this quality has given the following results:

Carbon, per cent	No. of ingots	Shipped yield, per cent	Average comparative yield, percent
0.04-0.06	8	86.5	76
0.04-0.06	22	84.0	76
0.04-0.06	11	82.5	76
0.07-0.09	22	82.5	76
0.07-0.09	22	84.5	76

The column in the foregoing table representing comparative yield is the yield of salable metal obtained at the plant in which those ingots were cast using regular practice with no hot tops. Hot tops are not used in the casting of steel of this class in that plant for the reason just given, i. e., because they do not increase the yield sufficiently to offset the cost of hot topping. The substantial increase in shipped yield resulting from the practice of the present invention is obvious, and it will be observed that it is at least five times that which is often considered necessary to justify hot topping. The benefit is really greater because the cost of practicing the present invention

is so materially less than that involve in using sink head hot tops.

In the same plant there were cast also eight large ingots of a killed steel containing 0.63 per cent of carbon, using the practice of the present invention. The shipped yield from these ingots was 86.8 per cent. In contrast yields of only 78 to 80 per cent are had in that plant in normal hot top practice with this particular class of steel.

At still another steel plant there were cast three heats of semi-killed low carbon silicon steel containing high phosphorus. The shipped yield of two heats was 84.7 per cent, and that of the third 86 per cent. The average yield with standard hot tops in that plant and with this particular grade of steel is 80 per cent. Accordingly the practice of the invention has increased the yield at least 5 per cent.

In another steel plant there were cast six ingots weighing 13,000 pounds each, which were rolled to 12x12-inch blooms. The yield was 85.5 per cent, an increase of 8 per cent over the yield had with standard sink head hot top practice in that plant.

In yet another plant fifteen ingots of 10,000 pounds each were cast from a heat of spring steel containing 0.62 per cent of carbon. These ingots showed a yield of 88 per cent as compared with the average of 73 to 74 per cent obtained with that steel on standard sink head practice.

Similarly beneficial results could be cited, obtained in commercial practice in various other steel plants. It may be said also, with reference to steel quality, that steel fabricators receiving ingots, or billets made therefrom, cast in accordance with this invention made not one complaint of piped metal, whereas they did complain of that drawback in metal cast using ordinary hot tops. In fact, a customer of one plant who had been getting hot topped metal ceased complaints when receiving metal cast according to this invention, without being aware of the change in practice. The complaints were renewed when the practice of the invention was temporarily discontinued, but they ceased again immediately on its resumption. This is significant in view of the increasing severity of specifications for in addition to direct savings the invention thus makes it easier to improve the quality of metal output and to meet stringent requirements.

The benefits of the invention will be realized further from the fact that extensive commercial practice of the invention shows that small-end-up ingots may be made with better recovery of salable metal than in the case of hot-topped large-end-up ingots to which the industry has turned in recent years in an endeavor to minimize metal losses due to pipe even though large-end-up ingots are more difficult and expensive to handle. Greater metal yields are being had with small-end-up ingots treated in accordance with the invention, than with large-end-up hot-topped ingots, and the quality of metal is fully the equal of that from the latter.

The use of a heat-resisting binder affords a structure which is substantially non-flammable if the base material has been covered with the binder. This prevents rapid destruction of the slab by the heat of the metal in the mould, and it avoids the disadvantages of the smoke and flame which accompany the use of a cover of loose straw or the like. At the same time, since the base material, such as wood shavings, is coated with a relatively thin layer of the refractory, the heat of the metal at the top surface of the ingot

will usually cause the wood to become charred, although this charring will generally be confined to the center of the slab, i. e., in the region of the axis of the ingot. Hence, when the metal has cooled and contracted so that back-pouring is necessary to provide molten metal for avoidance of piping, at least the central portion of the slab will have charred sufficiently that the metal may be poured directly through it. And even if the center portion is not charred, it can be broken through readily to permit refilling the ingot at the top of the mould.

Again, the material used in the practice of the invention is cheap, and the cost of the slabs is substantially less than that of the types of hot top used heretofore.

It will be seen also that metal losses are reduced not only through reduction in piping, but also because the sink head portion of the ingot which necessarily results in hot top practice is eliminated. This not only reduces the croppage losses, but also it reduces the amount of metal which must be poured per ingot and thus results in more ingots per heat.

In addition to the foregoing major advantages, the practice of the invention also results in another feature of major consequence, viz., decreased segregation, as has been demonstrated amply in the thousands of tons of steel cast in accordance with this invention. This appears to be due to the fact that in the practice of the invention there is backpouring of a considerable amount of metal after a cavity has been formed, in solidification of the ingot, but in which there is yet molten metal. While there may be segregation in the molten metal remaining in the cavity, due to the phenomena attending crystallization, the addition of a large amount of backpoured metal results in dilution of the segregated melt to bring it more nearly to the composition of the poured metal, thus minimizing segregation. The importance of this result to the steel maker and user needs no elaboration, but it again results in increased yields of useful product.

All of these factors combine to give greater recovery of useful metal, and to reduce costs.

In the practice of the invention the mould is filled with metal and the slab is then inserted in the mould opening. Experience has shown that the advantages described may be attained likewise where the mould is not entirely filled. For example, it may be desired to pour an ingot of a given size but no mould of that size is available. However, a larger mould may be used, the metal being poured to the necessary height and a slab of material disposed in the mould opening to rest on the metal surface in accordance with this invention, and the same advantages will accrue as in the case of moulds filled to the top. This making of "cuts" is not possible using ordinary hot tops, and the ability to do so in the practice of this invention is thus a further material advantage since it not only permits making ingots of a given size from a larger size mould, but particularly because it facilitates the turning out of small orders with a minimum of expense.

Although the invention has been described hereinabove with reference to a slab made from wood shavings bonded with refractory cement, it will be understood that various modifications can be made without departing from the essence of the invention. Wood shavings, or excelsior, due to their fibrous character and resiliency can be bonded to give a structure of high porosity.

Other fibrous materials might be substituted, such as plant stalks, for example, corn stalks, straw, and hay, or corrugated paper, or the like. Likewise, granular materials such as coke, cork, and other similar materials in the form of granules of such size as to produce adequate porosity and heat-insulating properties may be used in making the slabs. All of the materials named are cellular, which is desirable since it permits ready impregnation and since the use of cellular materials contributes to the attainment of suitable heat-insulating properties. The materials named are likewise combustible which is advantageous since it permits charring at the center portion of the ingot, as described hereinabove. It will be understood by those skilled in the art that other materials may likewise be used, such as refractory materials, provided they be bonded to produce the porous, hard, heat-insulating structure which characterizes the practice of the invention.

While the use of magnesium oxy-salt cements has been described as being preferred, it will be understood that other heat-resisting binders may be used, such as silicates and materials productive of silica or silicate bonds, or Portland cement, alumina cement, and the like materials adapted to satisfactorily bond the base of the slab into a porous structure and to provide adequate refractory properties to prevent rapid burning of the slab. So also there may be used non-refractory binders such as dextrine and others known in the art, plus an outer coating of refractory or heat-resisting material, such as magnesia, silica, and the like, but since this produces a heat-resisting product it is equivalent to the use of heat-resisting or refractory binder.

Furthermore, while it is preferred to insert the slab in the mould opening, it may be of such size as to rest on the top of the mould in instances where the mould is filled. Other modifications will occur to those skilled in the art.

According to the provisions of the patent statutes, I have explained the principle and method of construction of my invention and have described what I now consider to represent its best embodiment. However, I desire to have it understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

I claim:

1. That method of casting a metallic ingot which comprises the steps of pouring metal into an ingot mold, closing the mold opening with a slab of cellular combustible material bonded with heat-resisting material in the form of a porous, heat-resistant and heat-insulating structure of low mass-to-volume ratio which floats on the upper surface of the metal in the mold, and permitting the metal in the mold to solidify with concurrent charring of the combustible material in the slab, and thereby minimizing the piping and croppage losses in the ingot.

2. That method of casting a metallic ingot which comprises the steps of filling an ingot mold with said metal, closing the mold opening with a slab of combustible material in sub-divided form bonded with heat-resisting material and which is porous and heat-insulating and floats on the upper surface of the metal in the mold, permitting the metal in the mold to solidify with concurrent charring of the combustible material of the slab, and back-pouring to supply molten metal to the cavity formed by said solidification, and thereby minimizing piping and croppage losses of the ingot.

3. That method of casting a metallic ingot which comprises the steps of pouring metal into an ingot mold, closing the mold opening with a slab of wood shavings bonded with heat-resisting material and which is porous and heat-insulating and floats on the upper surface of the metal in the mold, and permitting the metal in the mold to solidify with concurrent charring of the combustible content of the slab.

4. That method of casting a metallic ingot which comprises the steps of pouring metal into an ingot mold, placing in the mold opening a cover slab of wood shavings bonded with refractory magnesian cement, which floats on the upper surface of the metal in the mold, said slab being porous and heat-insulating, and permitting the metal in the mold to solidify with concurrent charring of the combustible material of the slab, and thereby minimizing the piping and croppage losses.

5. A method of casting a metallic ingot in accordance with claim 4, said cement being magnesium oxychlorid cement.

6. A method of casting a metallic ingot in accordance with claim 4, said cement being magnesium oxysulfate cement.

7. A method according to claim 3 in which the metal solidifies to form a cavity at the upper end of the ingot, and in which the cavity formed by solidification of said metal is filled with said metal.

8. A method according to claim 4 in which the metal solidifies to form a cavity at the upper end of the ingot, and in which the cavity formed by solidification of said metal is filled with said metal.

9. That method of casting metallic ingots which comprises pouring metal into a series of ingot moulds, closing the opening of each mould after said pouring with a slab of heat-resistant bonded material which is porous and heat insulating, said material being charred or burned axially of the ingot, and pouring further metal into said moulds through said charred or burned region after the entire series has been poured.

10. That method of casting metallic ingots which comprises pouring metal into a series of ingot moulds, closing the opening of each mould after said pouring with a slab of heat-resistant bonded combustible material in sub-divided form which is hard, strong, porous, and heat insulating, said material being charred or burned axially of the ingot, and pouring further metal into said moulds through said charred or burned region after the entire series has been poured.

11. That method of casting metallic ingots which comprises pouring metal into a series of ingot moulds, closing the opening of each mould after said pouring with a slab of wood shavings bonded with magnesium oxysulfate cement to form a strong, porous and heat insulating slab, said shavings being charred or burned axially of the ingot, and pouring further metal into said moulds through said charred or burned region after a series has been poured.

12. Means for minimizing piping in ingots when cast, comprising a slab of wood shavings, said shavings being enclosed in and bonded with a magnesium oxysulfate cement, and said slab being light, porous, of low mass-to-volume ratio, and heat insulating.

13. That method of minimizing segregation in a metallic ingot which comprises pouring metal into an ingot mold, closing the mold opening with a heat-insulating and heat-resistant porous slab

of combustible material of low mass-to-volume ratio which floats on the upper surface of the metal in the mold, permitting the metal to solidify in the mold with concurrent charring of the combustible material of the slab and with formation of a cavity containing an amount of molten metal, and filling said cavity with a further amount of metal.

14. That method of casting metallic ingots which comprises pouring metal into a series of ingot molds, closing the opening of each mold after said pouring with a slab of heat-resistant bonded material which is porous and heat-insulating and floats on the surface of the metal

in the mold, said material being charred during solidification of the metal in the mold with concurrent formation of a shrinkage cavity, and pouring further metal into the molds after the occurrence of such charring to fill said shrinkage cavities.

15. Means for minimizing piping in ingots when cast, comprising a slab of combustible material bonded with a heat-resisting binder and being light, porous, of low mass-to-volume ratio, strong, heat-insulating, and being resistant to rapid destruction by the heat of the cast metal of the ingot but being slowly charred thereby.

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