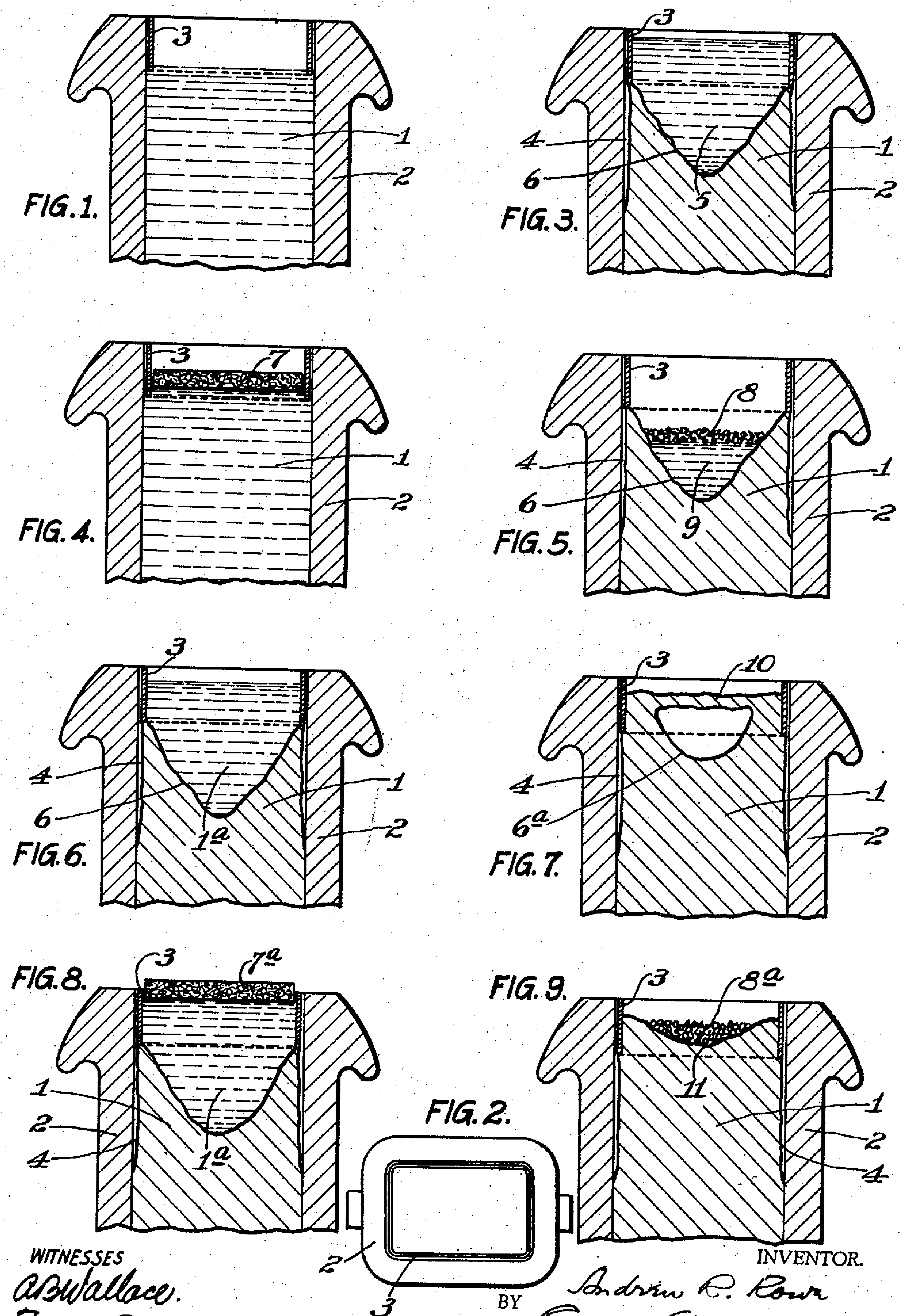
Feb. 28, 1939. A. R. ROWE 2,148,583

CASTING METALS

Filed Aug. 23, 1937 2 Sheets-Sheet 1



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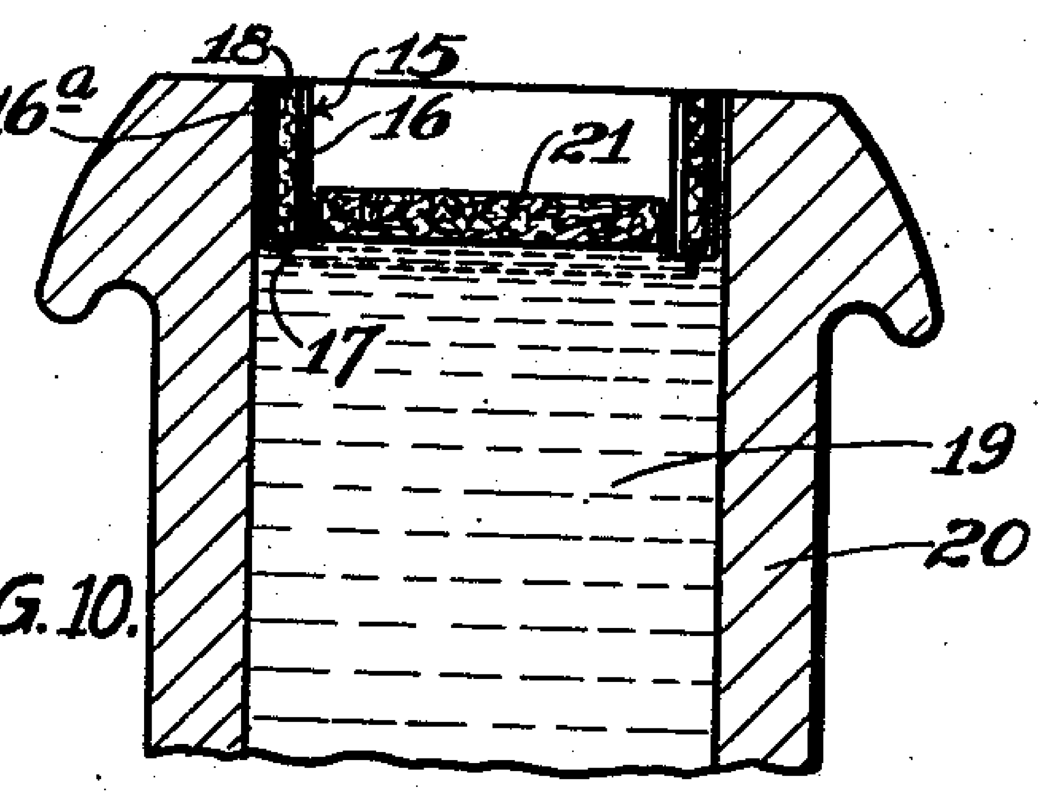

FIG. 10.

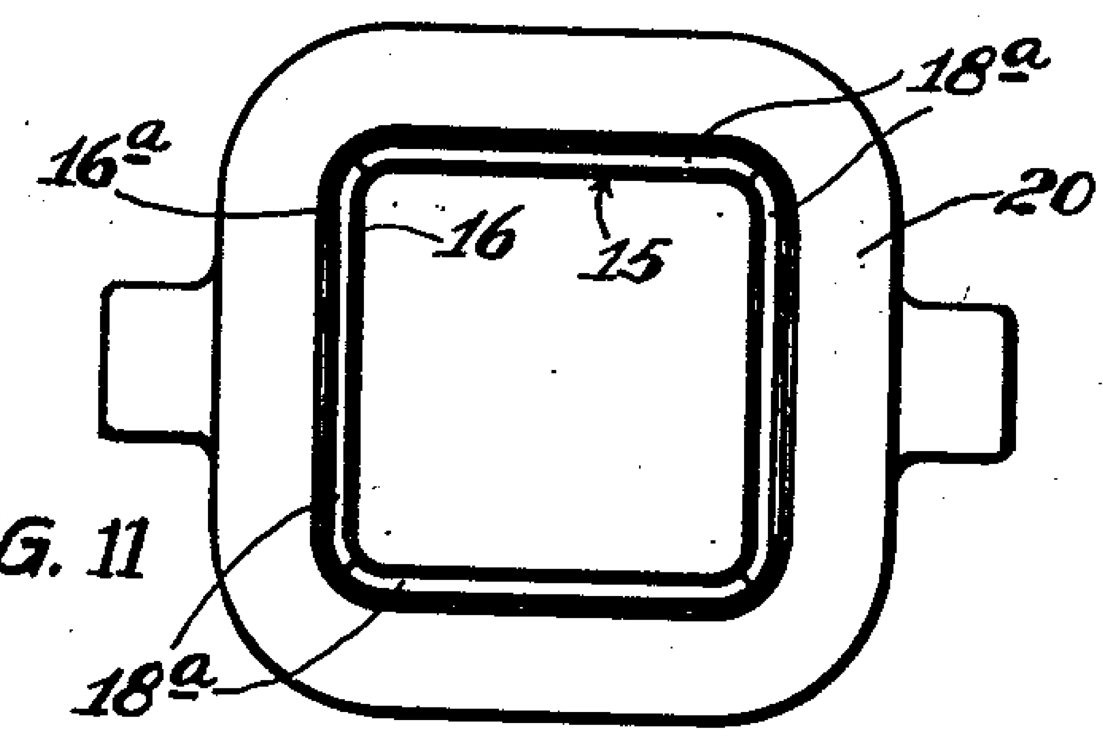

FIG. 11

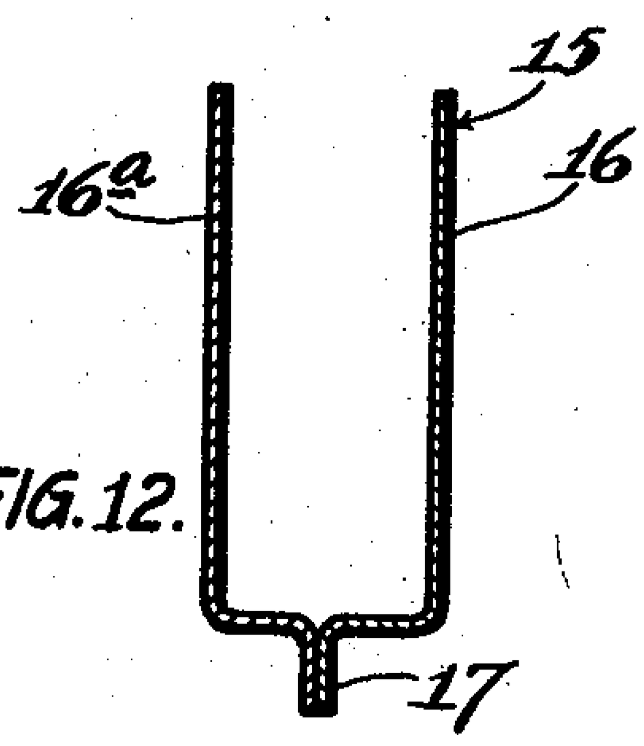

FIG. 12.

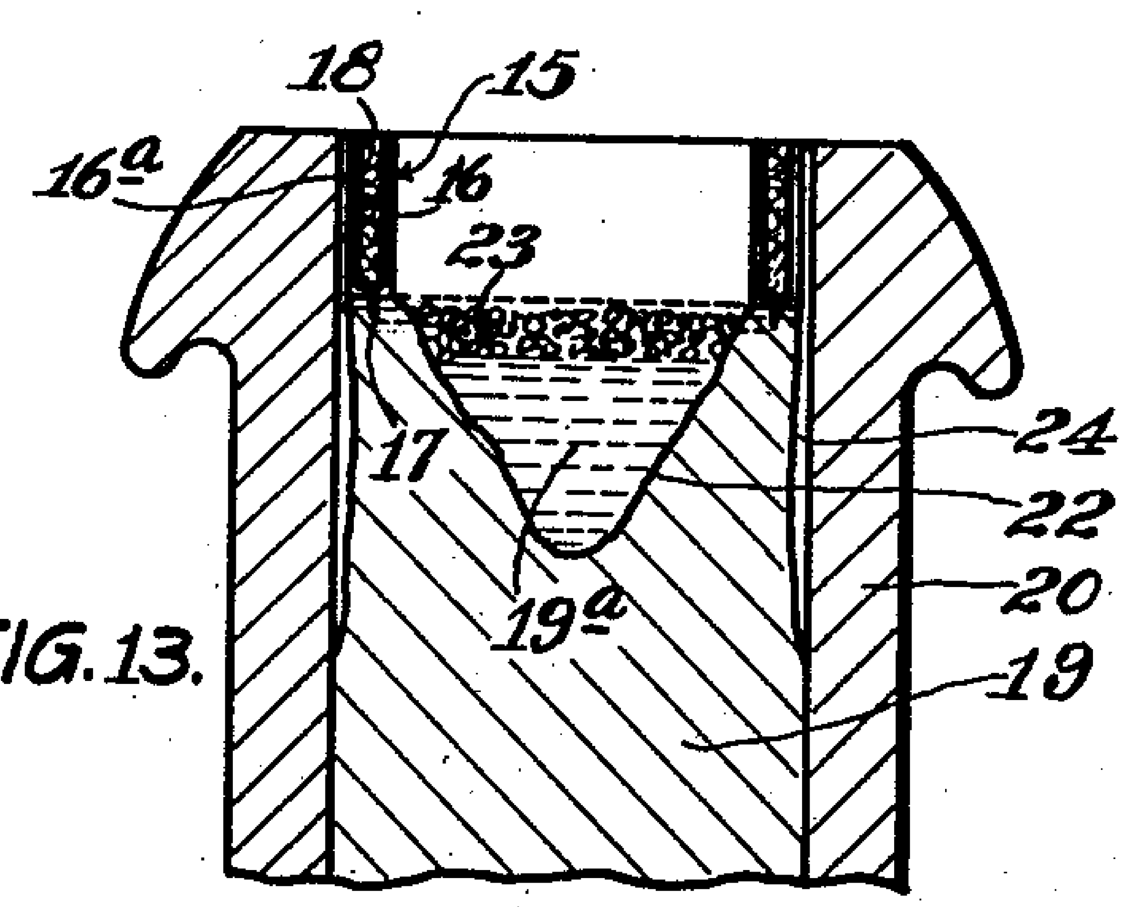

FIG. 13.

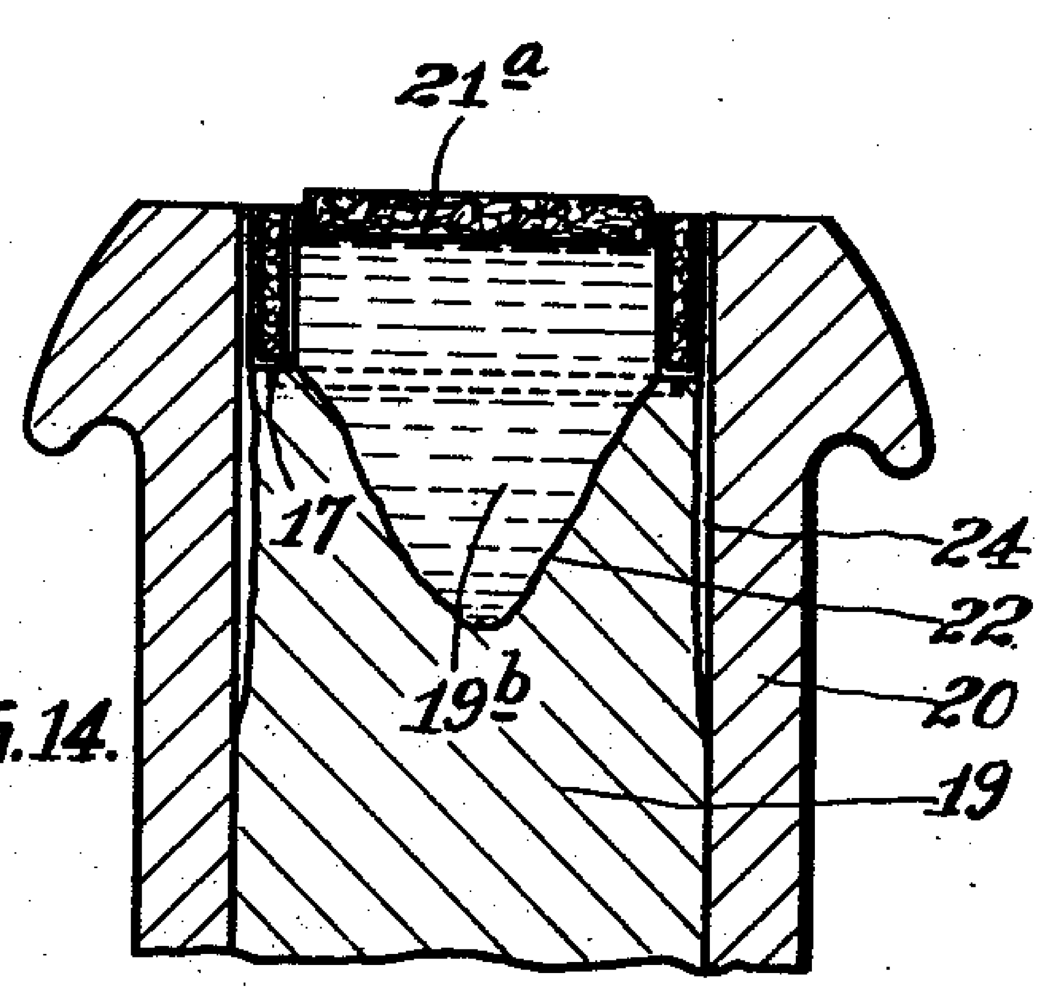

FIG. 14.

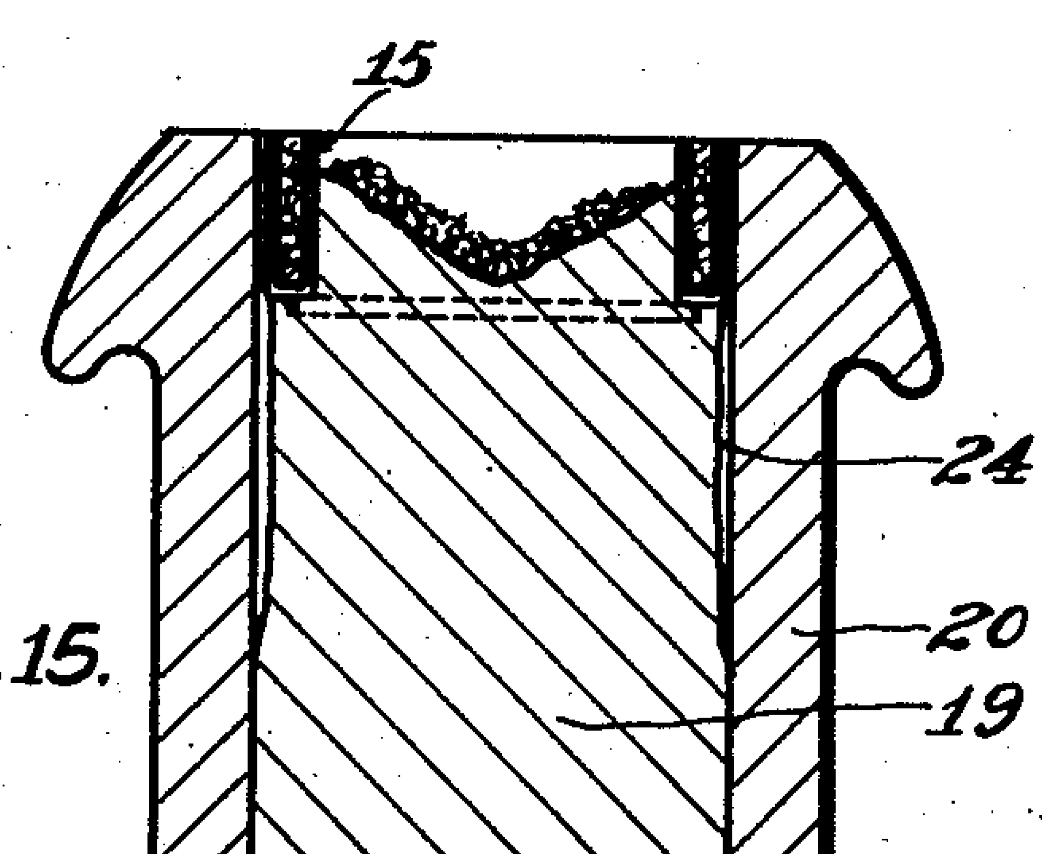

FIG. 15.

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UNITED STATES PATENT OFFICE

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CASTING METALS

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Application August 23, 1937, Serial No. 160,361

11 Claims. (Cl. 22—200)

This invention relates to improvements in the casting of metallic ingots, and particularly to the casting of ingots of steel for working.

It is among the objects of the invention to provide improvements in casting operations of the type referred to, and particularly to avoid run-downs in back-pouring, together with the difficulties and defects resulting from run-downs in prior practice. A specific object of the invention is to permit back-pouring while avoiding the formation of run-downs, coupled with increased yields of interiorly sound product. Other objects will appear from the following description, to those skilled in the art.

In the casting of metals for mechanical working, as by rolling or forging, and particularly in the manufacture of steel ingots, to which the invention is particularly applicable, the attempt is to provide ingots as free as possible from defects, particularly piping and blow-holes, which may, and commonly do, cause the formation of defective metal which is not salable. Accordingly, a common practice is to fill the mold to a predetermined height, permit the metal to solidify with formation of a shrinkage cavity, or pipe, and then to pour a further amount of metal into the mold to fill the initially formed pipe, which pouring is often referred to as "back-pouring," its object being to increase the proportion of sound metal in the ingot. One difficulty which may be encountered in such practice arises from the fact that as the initially poured metal solidifies and cools in the mold its shrinkage causes the formation of a space between the side of the ingot and the mold wall, and the size of this opening may be increased further in consequence of expansion of the mold. The space thus created between the mold wall and the side of the ingot may be quite substantial, especially in the case of large ingots, and when metal is back-poured into the mold it runs down into this space forming what are known as run-downs. Run-down metal welds imperfectly with the initially solidified metal so that the worked product has an imperfect surface which renders it unsalable, or of low value.

The invention may be described in connection with the accompanying drawings in which Fig. 1 is a vertical sectional view through the upper part of an ingot mold illustrating one embodiment of the invention; Fig. 2 a plan view of the top of the mold shown in Fig. 1; Figs. 3 to 9 views similar to Fig. 1 illustrating other aspects of this embodiment of the invention; Fig. 10 a view similar to Fig. 1 showing another embodiment of the invention; Fig. 11 a plan view of the mold shown in Fig. 10; Fig. 12 a vertical cross-section through the liner element shown in Figs. 10 and 11; and Figs. 13 to 15 views similar to Fig. 10 illustrating further steps in the embodiment exemplified by Fig. 10.

In accordance with this invention metal, such as steel, is cast into an ingot mold to fill the mold to a predetermined height, usually to a point adjacent the top of the mold. There is then inserted in the mold a tubular liner element corresponding in outline, or cross-sectional shape, substantially to that of the ingot mold but of somewhat smaller dimensions so that the liner may be inserted readily into the mold but will conform rather closely to its walls. The width of the liner is such that when positioned in the mold its inner wall will be spaced from the mold wall by distance greater than the shrinkage of the metal in the mold. At its lower end the liner is provided with a sharp edge which projects downwardly into the cast metal so that upon solidification of the metal the liner element is thus frozen into place and forms a continuation of the previously cast ingot. Back-pouring may now be effected without the danger of run-downs, so that through the practice of the invention it is possible to achieve the benefits of back-pouring, with consequent reduction in piping and the like, while concurrently avoiding the formation of run-downs. The invention is applicable to casting either big-end-up or small-end-up but in the latter case the upper end of the liner preferably does not extend substantially beyond the top of the mold.

Having reference to Fig. 1, steel 1 is cast into an ingot mold 2 represented as of conventional form, the metal being poured into the mold until the mold is substantially filled, say to within a few inches of the top. There is then inserted into the upper end of the mold a sheet metal liner element 3, which, as appears from Fig. 2, is shaped to conform to the mold opening. As appears from Figs. 1 and 2, liner element 3 is of such size that it may be inserted readily into the mold but so that it will lie closely adjacent to the mold walls. Also, in small-end-up practice the liner element is preferably of such height that its upper end lies substantially flush with the upper end of the mold, whereby the liner element lies entirely within the mold.

Being formed from sheet metal, the lower edge of the liner thus forms a relatively sharp edge which projects slightly into the molten metal in the mold, as appears from Fig. 1. The metal in the mold is then allowed to solidify, in accordance with regular practice, whereby there will be formed a space 4 between the upper end of the ingot and the mold wall. However, in solidifying the metal in the mold will freeze about the lower end of liner 3, thus firmly fixing its position in the mold and forming a tubular extension into which metal may now be poured without danger of its entering and running down into space 4. Run-downs are thereby avoided.

The back-pouring and other concurrent or subsequent treatment applied in the formation of the ingot may be effected in various ways. For instance, a further amount of metal 5 may be poured into the mold to fill the shrinkage cavity 6 and liner 3, as seen in Fig. 3. I now prefer, however, to make use also of special means for minimizing piping and for insuring the production of a maximum proportion of interiorly sound metal in the finished ingot. To this end the metal is teemed into the mold and liner 3 is inserted as just described. There is then promptly applied to the upper surface of the molten metal within the liner a cover of heat-insulating character whose purpose is to maintain liquid metal at the upper end of the mold so that it will feed into the pipe, or solidification cavity, due to solidification of the ingot. Suitably this cover is formed of heat-insulating material of low mass-to-volume ratio and of combustible character so that it will be charred or burned by the heat of the cast metal, but which will resist complete destruction for a substantial period of time.

Most suitably the cover takes the form of a slab prepared by bonding wood excelsior, preferably in the form of coarse and long wood shavings, with a suitable binder, advantageously a heat-resisting cement. Wood shavings are particularly suitable because they provide a base which is itself a poor conductor of heat, and because they can be formed into a slab having a desirable porous and heat-insulating character, while the shavings will burn, or char, so that the residue of the cover material may be rapidly and easily removed prior to back-pouring.

For most purposes the shavings should be of rather great length relative to their width because the heat-insulating property of the cover slab, which is one of its important characteristics, is derived from having the slab of rather open structure. If the shavings are too short they will mat together, provide a minimum of air spaces, and give a slab that may be too dense for many purposes. On the other hand, long shavings provide a slab having an especially desirable structure, embodying a large proportion of air spaces, and being thereby suitably heat insulating and of relatively light weight. For instance, a suitable starting material is afforded by treating 16-inch lengths of wood in a shaving machine to provide shavings 16 inches long, about $\frac{3}{16}$ inch wide, and about $\frac{1}{64}$ inch thick.

Refractory magnesian cements, suitably magnesium oxy-salt cement, for instance magnesium oxysulfate or magnesium oxychloride, are suitable heat-resisting materials for bonding shavings.

In the production of cover slabs for use in the practice of the invention 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 provided with a relatively thin coating of the cement, although to prevent unduly rapid burning they should be entirely covered by such a coating. The amount of cement to be used will depend upon such factors as the character of the shavings, the size of the ingots, the casting temperature, and the number of ingots to be cast in a series, so that it is not possible to state precise amounts of cement for all purposes. However, the optimum results are attained by having sufficient cement present to adequately bond the wood fibers and to prevent too rapid destruction of the cover slab after being applied to the molten metal. In the best practice of the invention the slab should resist destruction for a length of time such that liquid metal will be present in the initial shrinkage cavity in the ingot at the time when back-pouring is instituted.

After the shavings have been coated they are compressed to provide porosity adequate to give the desired heat-insulating properties. The pressed slab is then 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 cement which also bonds the whole into a rigid and strong board, or slab.

Covers of the type described provide a combination of properties which cooperate in the practice of the invention to materially improve ingot quality with consequent substantial economies as contrasted with prior ingot casting practice. The use of a porous slab having a low ratio of mass-to-volume affords high heat insulation for the metal at the top of the mold since the slab absorbs and radiates to the outer atmosphere relatively little heat. This provides for maintenance of molten metal at the top of the ingot during the early stages of solidification of the metal in the mold, which is desirable. The cover being progressively destroyed under the action of the heat of the metal, the metal will solidify at the top, but it remains long enough to insure the production of a dense and readily weldable structure at the upper end of the ingot, and to insure the presence of liquid metal in the initial shrinkage cavity when back-pouring is commenced.

In the practice of this embodiment of the invention liner 3 is inserted in the mold so that its lower end extends a short distance into the cast metal, and heat-insulating material is promptly applied to the surface of the metal inside of the liner. For most purposes it is preferred to use a slab 7, Fig. 4, of the type just described, the slab being of such size as to substantially close the opening within the liner and thus substantially to cover the exposed surface of the metal, thereby providing for maintenance of molten metal at the top of the ingot during the early stages of solidification of the metal in the mold.

As the metal solidifies the liner 3 is frozen in place and there is formed the primary, or initial, shrinkage cavity 6. By the time cover 7 has been destroyed there remain merely embers or ashes 8, Fig. 5, which float upon the surface of an amount of metal 9 which remains liquid in the lower portion of the shrinkage cavity 6. Fig. 5 represents the condition of the ingot just before back-pouring. Before liquid metal 9 solidifies completely, additional metal 1a is poured into the mold to bring the metal level within liner 3, suitably substantially to its top surface as shown in Fig. 6. It will be observed again that the formation of run-downs in shrinkage space 4 is prevented by liner 3.

Because of the relatively small volume of metal which is added by back-pouring, and because its top surface is exposed freely to the atmosphere, the upper surface freezes quickly to form a crust 10, Fig. 7, of solid metal which seals the top of the ingot. As the cooling of the ingot progresses the metal solidifies with formation of a new shrinkage cavity 6a under crust 10 and this cavity is hermetically sealed by the crust against the outside air so that the walls of the cavity remain unoxidized and in readily weldable condition. On subsequent rolling or working the clean surfaces of the cavity weld together to form solid metal in the portions of the ingot which would otherwise be defective and imperfectly welded without the protection and sealing effect of the frozen surface.

Residue 8 may, and usually will, be of substantial thickness. For example, in the case of a cover slab 3 inches thick made as described hereinabove using magnesium oxy-salt cement, the residue will be of the order of 1 to 1½ inch thick. It may be scraped or blown from the top of the ingot after the final back-pour but most suitably it is removed prior to the back-pour because if a piece of the ash remains on the surface at the time of back-pouring it may cause the formation of a pore in crust 10 with consequent possibility of oxidation of the metal in the secondary cavity 6a. Where, however, the top of the ingot is a substantial distance below the top of the mold it may be difficult to remove the residue quickly and adequately by such procedures but the ingot may be sealed off satisfactorily by applying a water spray to the top of the ingot. Such a practice chills the top surface of the metal and causes a crust to form promptly, and in addition it minimizes or eliminates the possibility of pore formation in the crust. Or, if desired, such sealing off may be accomplished by an air blast.

The formation of pipe may be further minimized or eliminated by teeming the ingot and back-pouring in the manner described hereinabove, and promptly applying to the surface of the back-poured metal another cover slab 7a, Fig. 8, e. g., similar to that applied in the first instance. This slab minimizes heat losses from the upper surface of the back-poured metal, thus maintaining for a maximum period of time a head of liquid metal 1a for feeding into the shrinkage cavity which forms as the back-poured metal solidifies in the ingot. Consequently piping will be reduced to a minimum, the ingot after final solidification having a small pipe 11, Fig. 9, at its upper end, there remaining, as before, a layer of embers or ashes 8a.

Although the invention may be practiced as described hereinabove, using a tubular liner made of a single thickness of sheet metal, I now prefer to use a liner 15, Figs. 10 and 12, comprising spaced sheet metal walls 16 and 16a joined at their lower ends, as by crimping, spot welding, or the like, to form a downwardly projecting rib 17 which in the embodiment shown is disposed substantially centrally between the walls. As in the embodiment just described, and as appears from Figs. 10 and 11, the shape and size of this liner are such that it will enter the mold and lie closely adjacent to the mold walls. When liner 15 is inserted in the mold after the ingot has been cast, rib 17 extends downwardly into the cast metal and is frozen as the ingot solidifies to fix the liner in position.

In this embodiment of the invention the space between the walls of the liner is preferably filled with heat-insulating material 18, which may be of any suitable type or character. The provision of a layer of heat-insulating material around the back-poured metal minimizes heat losses through the sides of the mold at its upper end, where heat losses are normally greatest but where it is most important to maintain liquid metal for feeding into the solidification cavity as it forms, and it is for this reason that this embodiment is preferred because thereby piping may be reduced to a minimum.

Although various kinds of heat insulation may be used, and in various forms, I now prefer to use bonded insulation of the type described hereinabove. Thus, as indicated in Fig. 11, the space between the walls of the liner may be occupied by four slabs 18a of wood shavings bonded with refractory cement similar to those described in connection with the preceding embodiment.

In this embodiment of the invention the best results are to be had by using also an insulating cover applied to the surface of the metal when the liner is in place, and the subsequent treatment of the metal may similarly follow with or without the use of a second cover slab applied to the surface of the back-poured metal, with concordant results. In this instance, however, due to the added insulating effect achieved through this form of liner, piping is further minimized through the combined use of the liner and the insulating cover, whereby increased yields of metal are obtained.

For example, steel 19 is cast in a mold 20, Fig. 10, liner 15 is set in place, and as soon as possible the surface of the metal is covered with insulating material such as a cover slab 21 of wood shavings bonded with refractory cement to provide the properties described hereinabove. As the ingot solidifies liner 15 will be frozen in place by the solidification of steel 19 around rib 17, and a primary shrinkage cavity 22 will be formed. If proper insulation has been provided an amount of liquid metal 19a will be present in cavity 22 when back-pouring is started, as after pouring a series of ingots, and on this metal there floats ash residue 23 of the cover slab which is removed as described hereinabove. Upon back-pouring the metal is prevented by liner 15 from running into space 24, formed between the ingot and the mold, so that run-downs are eliminated. The ingot is back-poured to fill, or almost fill, liner 15 with additional liquid metal 19b, Fig. 14, and if desired there may thereupon be applied another cover slab 21a, producing a fully solidified ingot as shown in Fig. 15.

While the invention has been described with reference to the pouring of a single ingot, it will be understood that its practice is of particular benefit as applied to the casting of a series of ingots. Thus, metal is poured to a predetermined height in a mold, usually to substantially fill the mold. Immediately upon completion of the pouring the liner is inserted and where the cover slab is used it is immediately applied. This operation is then repeated with a desired number of molds which are poured successively. Before the liquid metal has completely solidified within the first poured mold, back-pouring is commenced and continued successively throughout the series.

Various modifications may be practiced without departing from the essence of the invention. Thus, it has been described with reference to insertion of the liner after pouring the metal into the mold. If desired, however, the liner may be positioned in the mold prior to the pouring operation, as will be understood by those skilled in the art. Also, while the invention has been described with particular reference to covers made from wood shavings bonded with refractory cement, it will be understood that various modifications are possible in this element. Wood shavings or excelsior can be bonded to give a structure of high porosity, owing to their fibrous character and resiliency, and from this standpoint are most desirable, but other substances may be substituted such as plant-stalks, for example, corn-stalks, straw and hay, or heavy corrugated paper and the like. Likewise, other combustible materials, such as granular combustible substances, preferably those of porous character, may be used. As will be understood also, the cover need not necessarily be in bonded form but may be applied loose. Again, referring to the use of bonded insulating material, magnesium oxy-salt cements have been described as preferred but it will be understood that other binders may be used, such as silicates or cements or materials adapted satisfactorily to bond the material into a porous structure and to cooperate to prevent unduly rapid destruction of the slab.

According to the provisions of the patent statutes, I have explained the principle and mode of operation of my invention, and have illustrated and described what I now consider to be 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 illustrated and described.

I claim:

1. That method of casting an ingot which comprises casting molten metal into an ingot mold until the metal has reached a predetermined height therein, disposing in the mold above said cast metal a tubular sheet metal liner member whose cross-sectional shape corresponds substantially to that of the mold but is somewhat smaller than the mold opening, said liner having an edge at its lower end projecting into the cast metal and having its upper end not substantially above the top of the mold, the inner wall of said liner being separated from the mold wall by a distance greater than the shrinkage of said cast metal in the mold, permitting said cast metal to solidify about said edge and with formation of a central shrinkage cavity, and pouring an additional quantity of said metal into said mold to fill said cavity and said liner.

2. That method of casting an ingot which comprises casting molten metal into an ingot mold until the metal has reached a predetermined height therein, disposing in the mold above said cast metal a tubular sheet metal liner member whose cross-sectional shape corresponds substantially to that of the mold but is somewhat smaller than the mold opening, said member having an edge at its lower end projecting into the cast metal, and having its inner wall separated from the mold wall by a distance greater than the shrinkage of said cast metal in the mold, applying to the surface of the cast metal within said mold a heat-insulating cover of combustible material of low mass-to-volume ratio that is charred or burned during solidification of the ingot but which resists complete destruction for a substantial period of time, permitting said cast metal to solidify about said edge and with formation of a central shrinkage cavity, and pouring an additional quantity of said metal into said mold to fill said cavity and bring the cast metal level into said liner.

3. That method of casting an ingot which comprises casting molten metal into an ingot mold until the metal has reached a predetermined height therein, disposing in the mold above said cast metal a tubular sheet metal liner member whose cross-sectional shape corresponds substantially to that of the mold but is somewhat smaller than the mold opening, said member having an edge at its lower end projecting into the cast metal, and having its upper end not substantially above the top of the mold, the inner wall of said member being separated from the mold wall by a distance greater than the shrinkage of said cast metal in the mold, covering the surface of the cast metal within said mold with a heat-insulating cover of combustible material of low mass-to-volume ratio that is charred or burned during solidification of the ingot but which resists complete destruction for a substantial period of time, permitting said cast metal to solidify about said edge and with formation of a central shrinkage cavity, pouring an additional quantity of said metal into said mold to fill said cavity and bring the cast metal level into said liner, and at the final pouring removing residue of said cover material to quickly freeze the metal over the top surface and thereby hermetically seal the ingot.

4. A method according to claim 3, said cover being a porous slab of long wood shavings bonded with refractory cement.

5. That method of casting an ingot which comprises casting molten metal successively into a series of ingot molds until the metal has reached a predetermined height therein, disposing in each mold above said cast metal a tubular sheet metal liner member whose cross-sectional shape corresponds substantially to that of the mold but is somewhat smaller than the mold opening, said liner having an edge at its lower end projecting into the cast metal, and having its upper end not substantially above the top of the mold, the inner wall of said liner being separated from the mold wall by a distance greater than the shrinkage of said cast metal in the mold, promptly covering the surface of the cast metal within each mold with a heat-insulating cover of combustible material of low mass-to-volume ratio that is charred or burned during solidification of the ingot but which resists complete destruction long enough to maintain liquid metal in the ingot until the entire series has been poured, permitting said cast metal to solidify about said edge and with formation of a central shrinkage cavity, and pouring an additional quantity of said metal into the successive molds to fill said cavity and bring the cast metal level into said liner.

6. That method of casting an ingot which comprises casting molten metal into an ingot mold until the metal has reached a predetermined height therein, disposing within the mold above said cast metal a tubular liner whose cross-sectional shape corresponds substantially to that of the mold but is somewhat smaller than the mold opening, said member comprising sheet metal walls spaced apart a distance greater than the shrinkage of said cast metal in the mold and joined at their lower ends to provide a downwardly projecting rib which projects into the cast metal, permitting said cast metal to solidify about said rib and with formation of a central shrinkage cavity, and pouring an additional

quantity of said metal into said mold to fill said cavity and bring the metal level into said member.

7. That method of casting an ingot which comprises casting molten metal into an ingot mold until the metal has reached a predetermined height therein, disposing within the mold above said cast metal a liner member whose cross-sectional shape corresponds substantially to that of the mold but is somewhat smaller than the mold opening, said member comprising sheet metal walls spaced apart a distance greater than the shrinkage of said cast metal in the mold and joined at their lower ends to provide a downwardly extending rib which projects into the cast metal, and the member having disposed between said walls slabs of wood shavings bonded by refractory cement, permitting said cast metal to solidify about said edge and with formation of a central shrinkage cavity and pouring an additional quantity of said metal into said mold to fill said cavity and bring the metal level into said member.

8. A method according to claim 5, said tubular member comprising sheet metal walls spaced apart a distance greater than the shrinkage of said cast metal in the mold and joined at their lower ends to provide a downwardly projecting rib which forms said edge, and insulating material disposed in the space between said walls.

9. That method of casting an ingot which comprises pouring molten metal into an ingot mold until the metal has reached a predetermined height therein, disposing in the mold above said cast metal a tubular sheet metal liner member comprising sheet metal walls spaced apart a distance greater than the shrinkage of said cast metal in the mold and joined at their lower ends to provide a downwardly projecting rib, the cross-sectional shape of said member being substantially that of the mold but being of somewhat smaller external size to permit insertion in the mold closely adjacent the mold walls, said rib projecting into the cast metal, covering the ingot with heat-insulating combustible material of low mass-to-volume ratio which resists complete destruction for a substantial period of time, permitting said cast metal to solidify about said rib and with formation of a central shrinkage cavity, pouring an additional quantity of metal into said mold to fill said cavity and bring the cast metal level into said liner, and at the final pouring removing residue of said cover material.

10. That method of casting an ingot which comprises pouring molten metal into an ingot mold until the metal has reached a predetermined height therein, disposing in the mold above said cast metal a tubular sheet metal liner member comprising sheet metal walls spaced apart a distance greater than the shrinkage of said cast metal in the mold and joined at their lower ends to provide a downwardly projecting rib, the liner having insulating material disposed in the space between said walls, the cross-sectional shape of said member being substantially that of the mold but being of somewhat smaller external size to permit insertion in the mold closely adjacent the mold walls, said rib projecting into the cast metal and the upper end of the liner being not substantially above the top of the mold, covering the surface of the metal with a slab of wood shavings bonded with refractory cement and which resists complete destruction for a substantial period of time, permitting said cast metal to solidify about said edge and with formation of a central shrinkage cavity, pouring an additional quantity of metal into said mold to fill said cavity and bring the cast metal level into said liner, and prior to the final pouring removing residue of said cover material.

11. That method of casting an ingot which comprises pouring molten metal successively into a series of ingot molds until the metal has reached a predetermined height therein, disposing in each mold above said cast metal a tubular sheet metal liner member comprising sheet metal walls spaced apart a distance greater than the shrinkage of said cast metal in the mold and joined at their lower ends to provide a downwardly projectiing rib, the member having insulating material disposed in the space between said walls, the cross-sectional shape of said member being substantially that of the mold but being of somewhat smaller external size to permit insertion in the mold closely adjacent the mold walls, said member having said rib projecting into the cast metal and its upper end not substantially above the top of the mold, promptly covering the metal with a cover slab of wood shavings bonded with refractory cement and which maintains liquid metal in the mold until the series has been cast, permitting said cast metal to solidify about said edge and with formation of a central shrinkage cavity, pouring an additional quantity of metal successively into said molds to fill said cavity and bring the cast metal level into said liner, and at the final pouring removing residue of said cover material.

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