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A. B. KINZEL

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METHOD OF MAKING CAST METALS

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Fig. 1.

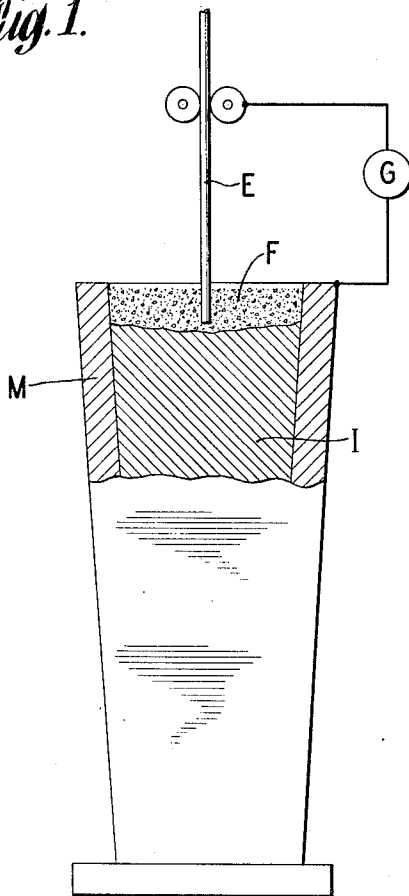
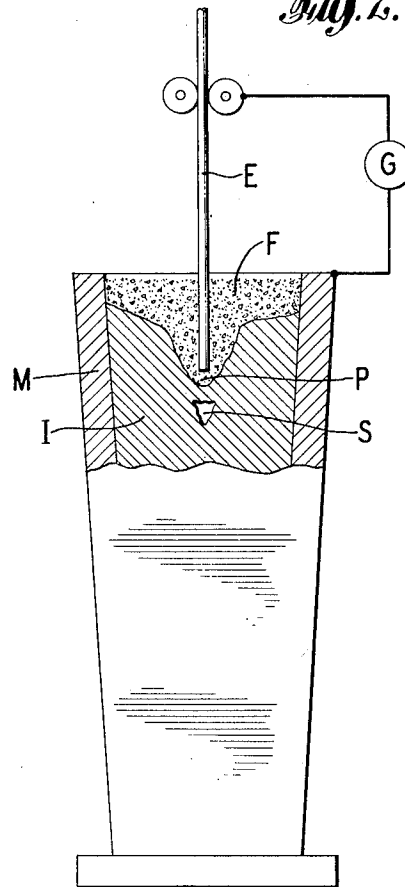


Fig. 2.



INVENTOR
AUGUSTUS B. KINZEL

BY *Freemewald*
ATTORNEY

UNITED STATES PATENT OFFICE

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METHOD OF MAKING CAST METALS

Augustus B. Kinzel, Douglaston, N. Y., assignor to
Electro Metallurgical Company, a corporation
of West Virginia

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6 Claims. (Cl. 22—216)

This invention relates to cast metals and has for its principal object the provision of sound cast metal bodies, such as ingots, substantially free from the shrinkage cavities and pipes normally present in such metal bodies. This application is a continuation-in-part of my applications Serial No. 142,725, filed May 15, 1937, and Serial No. 249,678, filed January 7, 1939.

Metal ingots which have been cast in the usual manner, by pouring the molten metal into suitable molds and permitting it to remain undisturbed therein until solid, ordinarily contain primary and secondary cavities and pipes in the top portion of the ingot, which is the last to solidify. Impurities in the metal also tend to segregate in the portion of the metal last to solidify. Consequently, the top portion of the ingot is not useful for the production of sound products of good quality and must be removed, generally by cropping, during fabrication of the ingot. Cropping, while heretofore considered necessary to ensure sound metal products, is undesirable in that it entails a considerable loss of ingot metal and necessitates the use of special additional operations and equipment. Analogously, the shrinkage cavities which occur in the risers of castings necessitate the use of larger risers which are later cropped with a resultant wastage of metal.

An object of the invention is to provide a novel method of eliminating primary and secondary shrinkage cavities or pipes in ingots or the risers of metal castings. Another object is to provide a method of cleansing and homogenizing the metal adjacent to the last-freezing portions of metal castings.

In accordance with the present invention, the above-described defects of cast metal ingots and other large castings and their manufacture are substantially eliminated and an ingot having a dense, clean, homogeneous structure throughout is provided. In accordance with the method of the invention, after molten metal has been poured into a mold, the top of the metal is covered with a relatively heavy blanket of slag-forming material of special characteristics, and sufficient heat is added, by means of electric energy and an electrode spaced from the casting, to melt at least a part of the slag-forming material and to establish a pool of molten metal in the upper or normally unsound portion of the casting. The molten pool is then cooled and solidified at a retarded rate. Solidification is effected at such a rate as to substantially prevent or eliminate cavities, segregated impurities, and other imperfections throughout most of the upper portion of the casting.

An outstanding characteristic of the method of this invention is the use of a sufficiently deep blanket of flux material to cover and conceal

the end of the electrode adjacent the casting, thereby blanketing or smothering the electric arc which would otherwise be visible. Whether a true arc is present under the blanket is conjectural and in any event of no practical importance to this invention. As long as the end of the electrode is blanketed, and the electric current is adequate, the improved results of the method are obtained.

The initial heating step may be commenced before, during, or after solidification of the metal in the upper portion of the ingot. Preferably, the heating is begun almost immediately after the pouring operation and before much of the ingot has solidified, as by this procedure the amount of heat necessary to establish the pool of molten metal and to carry out the treatment will be held to a minimum. Further, when the ingot is treated immediately after pouring, the upper portion of the ingot is caused to solidify progressively from the bottom to the top rather than from the sides to the center, thereby restricting the initial formation of cavities and other shrinkage defects. Under some circumstances, it may be expedient to commence the heating immediately after the primary shrinkage cavity has formed.

In the accompanying drawing which illustrates the method of the invention,

Fig. 1 is a diagrammatic partial cross-section of an ingot arranged to be treated before solidification is far advanced, and an apparatus suitable for carrying out the method, and

Fig. 2 is a diagrammatic partial cross-section of an ingot arranged for treatment after more or less complete solidification, showing a primary shrinkage cavity P and a secondary shrinkage cavity S, and an apparatus suitable for carrying out the method of the invention.

In the preferred form of my invention, illustrated by Fig. 1, molten metal is cast into an ingot mold M to form an ingot I. Immediately thereafter a quantity of unbonded non-metallic material (the characteristics of which are described hereinbelow) is placed on top of the ingot I to form a relatively deep blanket F. If desired, an enclosure such as a baked sand or brick hot top (not illustrated), may be employed to retain the blanket F on the top of the ingot I. An end of an electrode E, preferably graphite, is brought to a position slightly above the top surface of the blanket F. A source of electric current is connected across the gap between the end of the electrode E and the ingot I, and sufficient electric current, either alternating or direct, is passed through the electrode E and the blanket F to melt a portion of said blanket. The end of the electrode E is then inserted into the blanket F and maintained in that position, with a current flowing but the arc covered, for

a period sufficient to cause the entire upper portion of the ingot I to become molten, and to establish a pool of fused blanket material on the molten top of the ingot I. The electrode E is then retracted and the ingot I permitted to solidify undisturbed in the mold, the heat contained in the ingot I and the blanket F being sufficient to retard the rate of solidification. The length of time necessary to continue the melting operation, and the best conditions of voltage, current, and electrode diameter will depend largely on the size of the ingot, and the temperature necessary to melt the metal and to cause it to solidify at such a rate as to be substantially homogeneous in composition and structure.

In an alternate form of my invention, illustrated by Fig. 2, molten metal is cast in the usual manner to form an ingot I. The ingot I is permitted to remain undisturbed in the mold M until the metal at the bottom of the primary shrinkage cavity P has solidified. A quantity of unbonded non-metallic material is placed in the cavity P and on top of the ingot I to form a blanket F. The entire upper portion of the ingot I is then caused to become molten by means of an electrode E carrying sufficient electric current and introduced into the flux blanket F in accordance with the procedure described in connection with Fig. 1. The upper portion of the ingot I is maintained in a molten condition until the metal is substantially homogeneous in composition and free from cavities. If there are secondary cavities S to be removed, it is usually necessary to employ sufficient electric current to melt the roof of the cavities in order to cause molten metal from the ingot top to penetrate into and fill or otherwise eliminate such cavities.

In either procedure, during the cooling and solidification step the electrode may be maintained in an operating position and current supplied either intermittently or continuously. If continuously, it is preferably in a gradually diminishing amount.

While the use of one electrode will normally be sufficient to attain a satisfactory ingot, in the treatment of large ingots or in the elimination of very large shrinkage cavities it may be desirable to use two or more electrodes electrically connected in series or in parallel.

The electrode E may be infusible (of graphite, for instance) or of a fusible metal. If a fusible metal electrode is used, it is preferably of substantially the same composition as the metal of the casting to be treated. The end of a fusible electrode is melted progressively by the applied electric current, and this introduces additional metal to the casting. As the electrode melts, it may be fed towards the casting by a suitable electrode feeding device which may be similar to those used in conventional electric welding apparatuses. Enough electric current should be used to coalesce the deposited metal with the metal of the casting, and to introduce enough metal substantially to fill, or to overcome the formation of, pipes or other cavities.

The composition of the blanket material F is of particular importance. Suitable materials are substantially free from substances which would evolve gas during the ingot treating operation. They are fusible at a temperature in the neighborhood of the melting point of the metal of the ingot, and preferably at a temperature somewhat lower than the melting point of the ingot metal; are preferably a high resistance con-

ductor when molten and of such fluidity at the temperature of the molten metal that they will not readily be entrained in the molten metal; and preferably have a fairly sharp and definite melting point.

Materials which fulfill these requirements include various slags and fused silicates, for instance, calcium silicate, manganese silicate, calcium-magnesium-aluminum silicate, calcium-iron-manganese silicate. The foregoing may be used in conjunction with oxides of alkali metals or manganese, or halides of the alkali or alkaline earth metals. Various combinations of the above-mentioned materials may be used. I prefer to employ silicates of the alkaline earth metals, such as calcium silicate, to which has been added alumina or manganese oxide or both. The constituents may suitably be reacted, and volatile ingredients be driven off, by fusing the mixture in an electric furnace, and a definite melting point may ordinarily be imparted by chilling and rapidly solidifying the fused and molten mixture. The most convenient form of the material is as unbonded finely-divided grains of approximately uniform size. If desired, subdivided metals, for example, ferrochromium, ferrosilicon, or ferromanganese, may be added to deoxidize, or to modify the composition of, the treated ingot metal.

In the manufacture of ingots of certain types of steels a slight inhomogeneity of composition in the upper portion of the ingot is not seriously detrimental, either during the working of the ingot or in articles subsequently fabricated therefrom. However, in the manufacture of special alloy steel ingots, such as those of the corrosion resistant type, it is desirable that the ingot have a homogeneous composition as well as be substantially free from cavities. Consequently, in some instances it may be desirable to treat the metal primarily to eliminate cavities, making no particular attempt to obtain an ingot which is also homogeneous in composition; whereas in other instances care may be taken to produce an ingot substantially homogeneous in all respects.

The following specific example is representative of a typical procedure embodying the invention: An alloy steel containing 1% chromium; 0.4% copper; 0.08% carbon; 0.5% silicon and 0.3% manganese was prepared in the usual manner in an electric arc furnace. The steel was poured into a standard ingot mold thirty inches long by about eight inches square which was placed with the big end up, and which was provided with a hot top of baked sand. The hot top was so shaped that each side of the ingot mold presented a substantially uninterrupted surface from the top to the bottom of the ingot mold. Immediately after pouring, the top surface of the molten metal was covered with a blanket of about ten pounds of unbonded subdivided silicate obtained by melting together approximately two parts, by weight, of silica to one part of calcium oxide. A graphite electrode having a diameter of one inch and carrying a current of 600 amperes was held immediately above the blanket so that a short arc of sufficient intensity to melt a portion of the flux passed between the ingot metal and the electrode. The end of the electrode was then immersed in the molten flux and the current held at 200 amperes for a period of about fifteen minutes. No vertical adjustment of the electrode was necessary during this period, the amount of electrode consumed being only one inch.

Thereafter, the ingot was cooled, the mold stripped off, and the complete ingot forged in the usual manner to a slab four inches thick by eight inches wide, and this slab was subsequently rolled to a plate one-half inch thick by twelve inches wide. No evidence of cracking was discernible during the forging and rolling operations. The primary and secondary shrinkage cavities normally present in an ingot of this type had been completely eliminated, and throughout the entire section the metal was sound and of homogeneous chemical composition and structure. While the specific example herein described has been given in connection with the treatment of a low alloy steel ingot, equally good results have been obtained in the treatment of ingots composed of high alloy steels such as those of the 18% chromium-8% nickel type. Surprisingly, the treatment does not materially increase the carbon content of these steels.

The following specific example is another typical procedure embodying the invention: Six hundred pounds of a steel containing 18.8% chromium; 10.3% nickel; 0.09% carbon; 0.8% silicon; and about 0.5% manganese, was prepared in an electric arc furnace according to a procedure usual for this type of steel. After melting, the steel was poured into a standard eight inch square ingot mold which was placed with the big end down and which was not provided with a hot top. The ingot was permitted to solidify in the mold until the bottom of the primary shrinkage cavity had formed. The top surface of the ingot was covered with an unbonded subdivided silicate material containing, by proximate analysis: 29.2% CaO; 9.4% MgO; 50.9% SiO₂; 4.8% Al₂O₃, and 5.1% CaF₂. A bare filler rod of substantially the same composition as the ingot and having a diameter of one-quarter inch was introduced through the flux to the bottom of the shrinkage cavity. The filler rod was then melted into the cavity at the rate of about one to two pounds of metal per minute with an alternating current of about 900 amperes at 35 volts. After eight pounds of the filler metal had been deposited in this manner, the shrinkage cavity in the ingot was found to be completely filled. To determine its homogeneity, the ingot was stripped from the mold and the top portion cut longitudinally through the center. A cross-section of the ingot thus obtained was then etched and examined. It was observed that both the primary and the secondary shrinkage cavities normally present in an ingot of this type had been completely eliminated, and that throughout the entire section the metal was sound and of homogeneous chemical composition and structure. The homogeneous chemical composition is shown clearly in the following analyses of the deposited filler metal.

Sample taken at—	Composition			
	Percent Cr	Percent Ni	Percent C	Percent Si
Top of deposit.....	18.8	9.7	0.08	0.7
Bottom of deposit.....	18.8	9.3	0.07	0.6

It will be observed from a comparison of these analyses and the analysis of the ingot that the deposited filler metal is of substantially the same chemical composition as the ingot.

The high current densities which may be employed to superheat both the molten metal and

the fused composition cause the metal and slag to become highly fluid and impart a swirling liquid current to the highly fluid mass which effectively cleanses impurities from the upper portion of the ingot. By increasing the current density, it is possible to penetrate into the ingot to any desired depth, thereby eliminating deep shrinkage cavities and pipes and cleansing the metal in any portion of the ingot.

The elimination of shrinkage cavities and segregation by the process herein described permits the attainment of a homogeneous ingot of substantially the same composition and structure throughout. The ingot yield is substantially increased thereby and a considerable saving in the cost of manufacturing sound, good quality products is thus effected. This is of particular importance in the production of the relatively expensive high alloy steels.

Although I have described my invention more particularly in connection with ingots, the invention is applicable to the removal of defects in sand castings and to the treatment of the metal risers employed in the production of large castings.

I claim:

1. The method of forming a sound, pipeless metal casting, which comprises the steps of pouring a body of metal into a mold and, before said body has completely solidified, applying electrical energy through an electrode, spaced therefrom, to the normally unsound upper portion of the body; so controlling the electrical energy input that the metal in said upper portion is brought to a sufficiently fluid condition to eliminate voids in the ingot and to release impurities; and maintaining a deep blanket of flux over the molten metal, and over the end of said electrode to blanket the arc, during such application of electric energy.

2. The method claimed in claim 1, wherein the said electrode is of graphite and the said flux is composed chiefly of silicates and is substantially free from gas-evolving ingredients.

3. The method of forming pipeless castings which comprises pouring a main body of metal into a mold and, before said main body has completely solidified, introducing therein additional metal, in the form of a fusible electrode, in a quantity sufficient substantially to overcome the formation of pipes; fusing said electrode by electrical energy and causing said fused additional metal to coalesce with metal of the main body in the region where pipes tend to form; and maintaining a blanket of flux over the molten metal during the fusion and the coalescence.

4. The method of producing a metal casting having substantially no shrinkage cavity, which method comprises pouring the casting into a mold; cooling said casting until the bottom of the primary shrinkage cavity has solidified; while the center of the casting is still molten, filling the shrinkage cavity with a comminuted nonmetallic material essentially comprising a fusible silicate or its equivalent; inserting, maintaining in, and progressively feeding into the material a metal electrode of substantially the same composition as the casting; and passing between said electrode and the metal adjacent to the cavity an electric current of sufficient magnitude to melt the electrode and the metal adjacent to the bottom of said cavity and to coalesce the molten metal with the wall of said cavity.

5. A method of forming pipeless cast metal ingots comprising the steps of pouring molten

metal from a molten metal source into a mold, incorporating metal by electric energy and a fusible electrode to supply metal in quantities sufficient substantially to compensate for the loss of volume of said cast metal during the cooling and solidification thereof, and maintaining a blanket of flux over the added metal during the incorporation of the metal with the molten metal of the casting before complete solidification of said poured metal.

6. A method of forming pipeless cast metal ingots comprising the steps of pouring molten

metal from a molten metal source into a mold, intimately bonding by electric energy added metal with the metal of the ingot in unsound portions of the ingot until said added metal commingles and becomes an integral part of the metal of the ingot and displaces impurities and fills voids in the ingot, and incorporating said added metal before complete solidification of the ingot, and maintaining a flux blanket over the fusing metal during the operation.

AUGUSTUS B. KINZEL