July 8, 1941. R. K. HOPKINS 2,248,628

METHOD OF CASTING METAL BODIES

Filed Aug. 28, 1937

FIG. 1

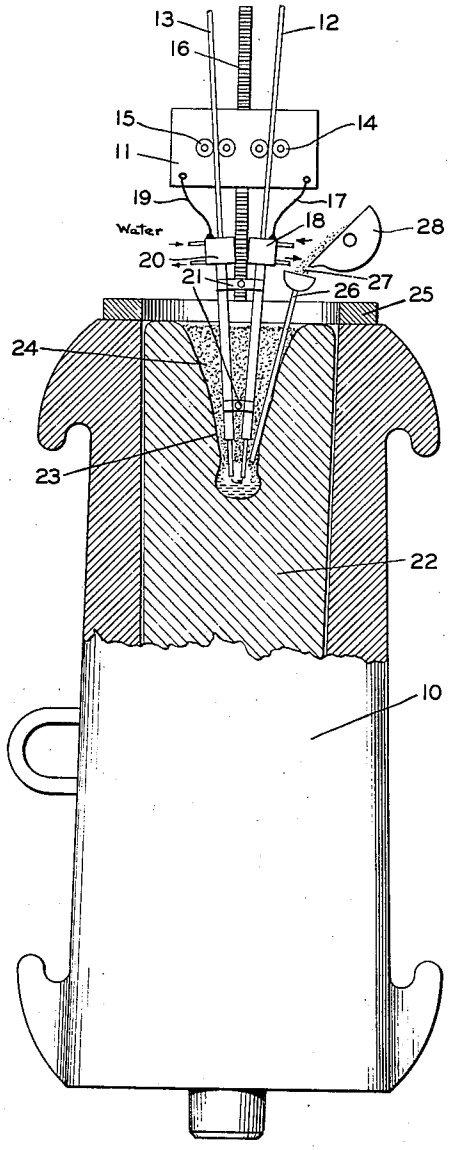
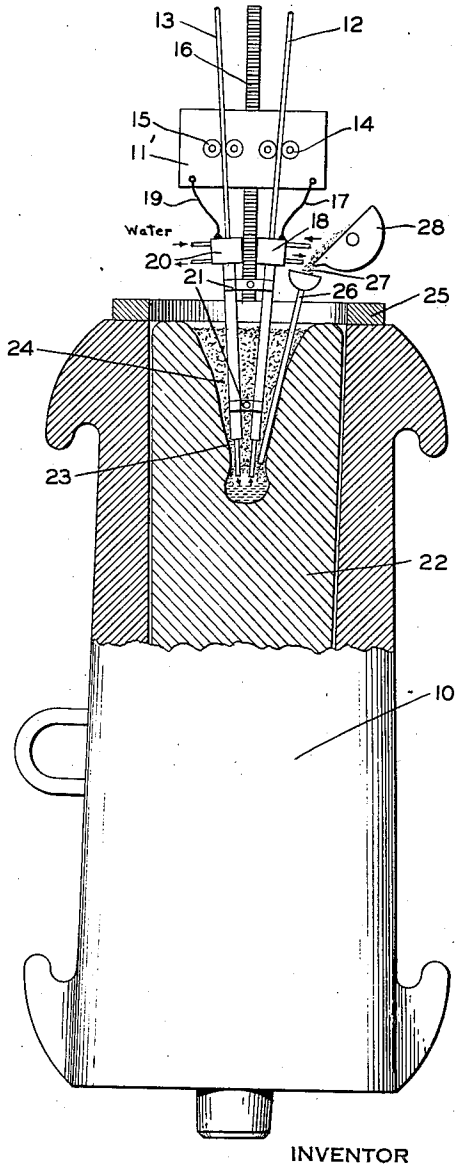


FIG. 2



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METHOD OF CASTING METAL BODIES

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4 Claims. (Cl. 22—216)

This invention relates in general to the casting of metal bodies and in particular to an improved method for casting metal bodies in which a maximum of dense sound metal is produced from the metal cast.

Metal sold in the form of worked shapes is generally cast into ingots preparatory to the working operations. The casting of the ingots is an important operation as the quality of the final product, as well as the salable yield, is largely determined by the quality of the ingots. A great deal of time and effort have been expended in perfecting ingot molds and casting technique with the result that in the present practice many of the causes of unsound metal have been eliminated. One of the main causes for the lowering of the salable yield, particularly with killed steels and comparable materials, is the pipe or pipes that form in the upper end of the ingot during the cooling of the cast metal. During the cooling and solidification of the cast metal furthermore, some of the impurities segregate out, the segregated material migrates inwardly and is found in the metal around and below the pipes.

In my copending application Serial No. 125,024 filed February 10, 1937, I disclosed a novel method for forming sound pipeless ingots in which the loss in volume of the metal of the ingot, that takes place during the cooling thereof and that results in the usual pipe or pipes, is compensated for by the deposition of molten metal in the ingot, which molten metal welds to the metal of the ingot and thereby produces a sound pipeless ingot. The metal deposited is preferably deposited as fusing weld metal under the influence of the discharge of electric current through a gap between the end of the electrode and the ingot metal. The metal deposition is carried out under a blanket of flux that protects the metal of the ingot and the deposited metal from the atmosphere and also absorbs or floats out impurities and segregations from the molten metal. The metal deposition may be initiated during the cooling and solidification of the cast metal or it may be initiated after the cast metal has been completely solidified.

The present invention relates to the novel method disclosed in my copending application, above identified.

In accordance with one aspect of the present invention a plurality of electrodes are employed and the welding current is discharged through a gap or gaps between their ends so that substantially all of the heat evolved by reason of the current flow is evolved at the gap or gaps and is effective to fuse the filler metal, the metal of the ingot and adjacent the walls of the pipe, or pipes, and to weld the filler metal to the metal of the ingot. The electrodes may all be consumable and the only supply of filler metal, or all of the electrodes may be substantially non-consumable and all of the filler metal supplied from an outside source. Also, some of the electrodes may be consumable and others substantially non-consumable. The outside source of filler metal may be a solid rod, bar or the like, and is inserted into the ingot in the region of the current discharge so that it may be fused by the heat generated by the discharge. The outside source may also be molten metal which is passed to the region of the current discharge to be heated to the degree required to cause it to commingle with and become an integral part of the metal of the ingot.

The plurality of electrodes, furthermore, may be so charged and arranged that the current is discharged from one or more of them through a gap or gaps to the cast metal and from the cast metal through a gap or gaps to another or others of the electrodes. In this arrangement, also, no current is dissipated by resistance in the walls of the ingot at a distance from the locus of the metal deposition so that the maximum advantage is had of the power employed.

The further objects and advantages of the invention will be readily appreciated from a consideration of the following detailed description of the mode of carrying it out in practice, taken with the accompanying drawing in which,

Fig. 1 is a view partly in side elevation and partly in section illustrating one way of carrying out my invention in practice, and

Fig. 2 is a view similar to Fig. 1 illustrating another way of carrying out my invention in practice.

The method of this invention may be used in connection with the forming of metal ingots in general and is not limited to any particular type of ingot or ingots of metal of any particular composition. However, since it is admirably suited to the formation of ingots of partly, or completely, deoxidized steel, it will be particularly described in connection with this type of metal.

The mold employed may be a big end up mold or a big end down mold and a hot top or similar device may or may not be used as preferred. If a hot top is used the relative volume thereof may be materially reduced below that of the best present practice. Thus, a hot top that contains

approximately 5% of the metal of the ingot will be more than ample. It should be obvious that if a hot top is used the pipe need only be filled to the crop line as no advantage is obtained by going above this line.

In Fig. 1 is shown an ingot mold 10 of the large end up type. The hot top has been omitted for simplicity's sake as its use is optional. As is usual mold 10 is made of cast iron.

The apparatus schematically shown in Fig. 1 includes a head 11 that is adapted to feed two electrodes 12 and 13. Head 11 may be arranged in any desired way to feed current at substantially constant values to the electrode ends and to maintain a more or less constant gap between them. At present, I prefer that head 11 include electrode feed wheels 14 and 15 arranged to drive electrodes 12 and 13 at an angle one to the other. The spacing between feed wheels 14 and 15 and the angle of drive should be such that electrodes 12 and 13 may be inserted to the bottom of the usual pipe cavity and a predetermined gap maintained between their ends. In order to facilitate the maintenance of the predetermined gap, head 11 is preferably mounted on a stand 16 so that it may be raised, as by means of a wheel and rack, as required to keep the ends of electrodes 12 and 13 adjacent to but out of contact with the molten metal. In the operation of this apparatus the space between the ends of the electrodes and the bottom of the pipe cavity, or the top of the molten pool after the operation is started, should always be greater than the gap between the electrodes. One of the feed wheels 14 and 15 is arranged to feed its electrode at a predetermined rate, the arrangement being such that the rate of feed may be changed at will to suit the necessities of each particular operation. The other of feed wheels 14 and 15 is so arranged that its feed is controlled by the characteristics of the current flow through the gap so that its feed will be such as to maintain substantially constantly a gap of predetermined width.

Head 11 may include a current generator (not shown) or may include connections to an outside current source. The current is passed from head 11 by cable 17 to connect device 18 through which is fed electrode 12. The other side of the current is passed from head 11 by cable 19 to contact device 20 through which is fed electrode 13. Contact devices 18 and 20 may be of any preferred construction. With welding electrodes whose surface is conductive I, at present, prefer to employ an elongated water cooled contact nozzle as shown. Contact devices 18 and 20 are held together by members 21, which are made of insulating material, so as to facilitate the maintaining of the predetermined angle between the electrodes.

Each of electrodes 12 and 13 may be either consumable or substantially non-consumable. At present, I prefer to make both of the electrodes consumable and of such analysis that when fused with the metal of the ingot the resulting metal is of substantially the same composition as the metal of the ingot. Electrodes 12 and 13 may be bare or covered and either solid or hollow. If covered, contact devices 18 and 20 should be such that they can pass the current continuously to the metal cores of the electrodes. All of the constituents of the electrodes may be incorporated in the metallic portions thereof, or some of them included in the metallic portions and the remainder in the coating, if one is used, or passed to the region of the gap between the electrodes in any suitable way, as for instance, if one or both of the electrodes are hollow, through the hollow center or centers, or also by employing a hollow body through which they can be passed to the region of the gap, or by introducing them through the flux blanket.

If the electrodes are substantially non-consumable, the metal required to fill the pipe or pipes may be supplied by feeding a metal rod to the region of the gap to be melted by the heat generated by the current discharge, also, it may be supplied to the vicinity of the gap as molten metal. Either or both of these expedients may also be used when either or both of the electrodes are consumable.

The apparatus schematically shown in Fig. 2 is generally similar to that of Fig. 1 and has been correspondingly numbered. Head 11', however, is so arranged that both of the feed wheels feed the electrodes in accordance with the characteristics of the electrical energy discharged so as to maintain the gaps substantially constant in width. When operating with the apparatus of this figure each of the gaps is maintained smaller than the space between the ends of the electrodes to prevent direct discharge from one electrode to the other.

In carrying out my novel method, the metal to be cast, as for instance, carbon steel, is prepared in the usual manner. Thus, the required additions are made and the molten metal is either partly or entirely deoxidized by the addition thereto of ferro-silicon, aluminum, or other preferred deoxidizing agents, and then allowed to come to the preferred pouring temperature. It is then poured into mold 10 and allowed to cool.

When the cast metal has cooled to such a point that the sides of the ingot have solidified and substantially all of the molten metal that is left is to be found in the region of the usual pipe or pipes the ingot is ready for the addition of fusing metal. This condition of the ingot is readily determined by sounding it from time to time as with a metal bar. With any type and size mold and with any analysis of cast metal the proper condition of the ingot is readily ascertained by any skilled operator by following the above relatively simple procedure.

Head 11 is then placed over ingot 22. Electrodes 12 and 13 are then passed to feed wheels 14 and 15 and fed through contact devices 18 and 20 until they almost touch each other. An arc started such as a wad of steel wool, a sliver of graphite or the like, is placed between the electrodes after which head 11 is lowered until the ends of the electrodes approach the bottom of the central cavity or pipe 23 of the ingot. Pipe 23 is then filled or partly filled with flux 24 which may be either solid or molten. A dam 25 may be provided to maintain flux 24 on ingot 22 when it is displaced by the deposited filler metal.

Flux 24 should be such that it will not liberate deleterious gas, either as to quantity or kind, during the metal depositing operation, and will not add substantial quantities of undesirable ingredients to or remove substantial quantities of desirable ingredients from the molten metal but will flux out impurities. A wide variety of fluxes may be used satisfactorily. Silicates in general, either simple silicates or mixtures thereof, or complex silicates or mixtures thereof, are satisfactory fluxes. Aluminates, titanates and similar compounds are likewise satisfactory. The flux need not be composed of reacted materials but may be made up of their unreacted

components, thus, for instance, in the case of calcium silicates the flux may be made up of CaO and SiO_2, in the case of manganese silicates it may be made up of MnO and SiO_2. At present, silicates, either simple or complex of the alkaline earth metals, manganese, aluminum and iron are preferred. Flux 24 may also include constituents of the metal to be deposited. Some of the steel finishing slags make satisfactory fluxes, for example, the slag produced in the manufacture of chrome-iron alloys. These slags, if convenient, may be ladled while molten directly from the steel furnace.

After flux 24 has been placed in pipe 23, as above stated, the electrical energy circuit is closed and the metal depositing operation begun. The initial flow of current will destroy the arc starter and provide an ionized path for the flow of current through the gap between the ends of the electrodes. The flow of current through the gap will consume the electrodes and generate sufficient additional heat to melt metal of the ingot and to intermingle the metals thus molten and fuse them to the ingot. Head 11, as stated above, will maintain a gap of predetermined width during the operation. As the level of the molten metal rises in pipe 23 the operator will raise head 11 as required to maintain the space between the electrodes and the molten metal greater than the width of the gap between the electrodes. The operator, by watching the volt meter of head 11 will become aware of the necessity of raising head 11 for if the ends of the electrodes discharge directly to the molten metal the voltage reading will be less than the predetermined value.

The procedure when the apparatus of Fig. 2 is employed is generally the same. However, with the latter apparatus head 11' is raised from time to time merely to prevent contact devices 18 and 20 from being destroyed as the control arrangements will always maintain the predetermined gaps.

When operating with the apparatus of Fig. 1 the ingot is not in the electrical circuit at all and with the apparatus of Fig. 2 only a very small zone of the ingot is in the circuit.

Thus, in both cases all of the energy dissipated is available to melt metal and fuse it to the ingot; no energy is dissipated by electrical resistance in the body of the ingot removed from the zone of deposition.

While the current input is largely determined by the amount of metal to be deposited and the time available for its deposition, I find it very advantageous to initiate the operation at high current inputs and gradually reduce the current input as the operation progresses. Thus, for instance, the operation may be started at an amperage in the vicinity of 10,000 amperes per inch diameter of electrode and finished at an amperage in the vicinity of 2000 amperes per inch diameter of electrode. The values just given are illustrative only and higher or lower values may be used as required to obtain the desired results in each particular case. The high initial current is highly desirable as it provides for the generation of heat at a rate high enough to assure the complete fusion of the metal at and below the bottom of the pipe and thus, porosity and segregation in this region are eliminated. The tapering off in current input assures the solidification of the metal deposited in the upper end of the pipe at a rate that approaches the rate of deposition so that at the end of the operation there is very little molten metal and, hence no porosity, segregation or piping in the top of the ingot. The current may be tapered off to the value above given, or to a much lower value as required to give the results stated.

In order to assure complete fusion of the metal deposited with the metal of the ingot, especially when the pipe is wide, the head 11 (or 11') may be given an oscillatory and/or rotary movement relative to the ingot so that all portions of the sides of the pipe will come into the direct influence of the current discharge.

The cost of the operation may be materially reduced in some cases by employing an additional source of filler metal. The additional source may take the form of a filler rod or molten metal. When a filler rod is used it may be fed to the vicinity of the gap, or gaps at a regulated rate but care should be exercised to so control the feed that the additional metal does not absorb too much of the energy of the operation and prevent a proper fusion and commingling of the metal of the ingot with the deposited metal.

When molten metal is employed for this purpose it may be poured directly onto the flux to pass by gravity to the molten pool, this easily takes place for the flux is either molten when placed in the pipe, as above stated, or if solid when placed in the pipe it becomes molten as the metal depositing operation progresses. The molten metal may also be passed from ladle 28 through a ceramic, or other high heat resisting material, tube or trough 26. The trough or tube is preferably positioned in the pipe before the pipe is filled with flux. As the operation progresses trough 26 is withdrawn as required to keep it away from the level of the fused metal. The molten metal may be taken from the heat that went to form the ingot or from some other molten metal source. Ladle 28 is preferably insulated and provided with heating means so that the metal in it may be maintained fluid for the duration of the pipe filling operation.

The molten metal may be passed into the pipe at a more or less constant rate or it may be passed into it intermittently. Again it is necessary to guard against feeding this metal at too high a rate so that it may be properly fused and intermingled with the metal of the ingot.

As previously stated, the electrodes may be made of material that does not supply metal for the operation. When this variation of the method is carried out all of the metal required may be supplied from the filler rods or ladle 28.

The method of this invention may also be employed to fill the pipe cavities of ingots, or cavities in metal bodies of whatsoever character such as castings, forgings and the like, after all of the metal thereof is solidified, or solidified and cooled to room temperature. In the cases just mentioned, the procedure is the same as that heretofore described, however, when filling the pipes of completely solidified ingots the high initial current input becomes more important and it is necessary that it be of a high enough value to assure the melting of a substantial portion of the ingot metal below and around the bottom of the pipe cavity so that the imperfect metal usually found there may be remelted and cleaned.

It is my present belief that in the operations above described, the heat is generated by an arc discharge. Since the fluxes mentioned are conductors of electricity when molten it has been advanced that the heat is generated by flow of current through the molten flux. As this applica-

tion is a disclosure of fact, it is to be understood that I do not wish to be bound or limited in any way by any theory advanced and that the appended claims are to be interpreted and construed in the light of the factual disclosure and the prior art regardless as to the correctness of the theory underlying the generation of heat.

I claim:

1. A method of increasing the yield of sound metal in metal bodies which comprises casting molten metal into a mold, coalescing metal with said cast metal by electric energy discharge under a blanket of flux to fill the cavity formed in said cast metal, said discharge taking place between a plurality of metal electrodes, the electric energy supplied for said discharge being supplied to said electrodes, and passing molten metal from an outside source to be coalesced by said energy discharge with said cast metal and the metal of the electrodes.

2. A method of increasing the yield of sound metal in metal bodies which comprises casting molten metal into a mold, coalescing metal with said cast metal by electric energy discharge under a blanket of flux to fill the cavity formed in said cast metal, said discharge taking place between a plurality of metal electrodes, the electric energy supplied for said discharge being supplied to said electrodes, passing metal from an outside source to be coalesced by said energy discharge with said cast metal and the metal of the electrodes, said energy discharge being of such magnitude at the beginning of the coalescing operation that substantial quantities of cast metal at the bottom of said cavity are fused whereby porosity and segregations at the bottom of said cavity are eliminated.

3. A method of increasing the yield of sound metal in metal bodies which comprises casting molten metal into a mold, coalescing metal with said cast metal by electric energy discharge under a blanket of flux to fill the cavity formed in said cast metal, said discharge taking place between a plurality of metal electrodes, the electric energy supplied for said discharge being supplied to said electrodes, passing metal from an outside source to be coalesced by said energy discharge with said cast metal and the metal of the electrodes, said energy discharge being of such magnitude during the latter stages of the coalescing operation that the metal is fused at a rate that does not substantially exceed the rate of solidification of the fused metal, whereby at the end of the coalescing operation comparatively small quantities of molten metal are present.

4. A method of increasing the yield of sound metal in metal bodies which comprises casting molten metal into a mold, coalescing metal with said cast metal by electric energy discharge under a blanket of flux to fill the cavity formed in said cast metal, said discharge taking place between a plurality of metal electrodes, the electric energy supplied for said discharge being supplied to said electrodes, passing metal from an outside source to be coalesced by said energy discharge with said cast metal and the metal of the electrodes, said energy discharge being of such magnitude at the beginning of the coalescing operation that substantial quantities of cast metal at the bottom of said cavity are fused, the magnitude of said energy discharge being tapered off as the operation progresses whereby at the end thereof only comparatively small quantities of molten metal are present.

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