Nov. 13, 1945. R. K. HOPKINS 2,388,974

METHOD FOR CASTING METAL

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Fig. 1.

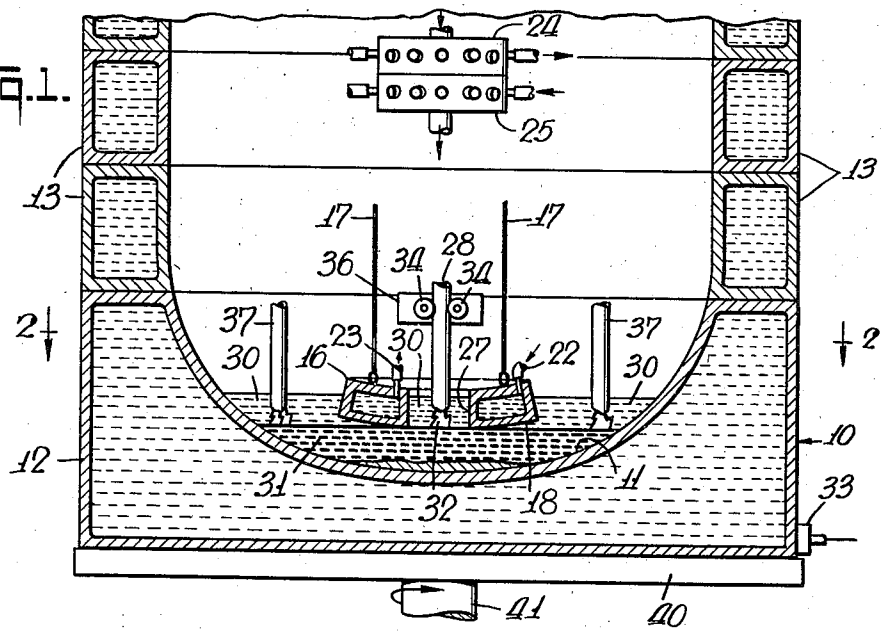


Fig. 2.

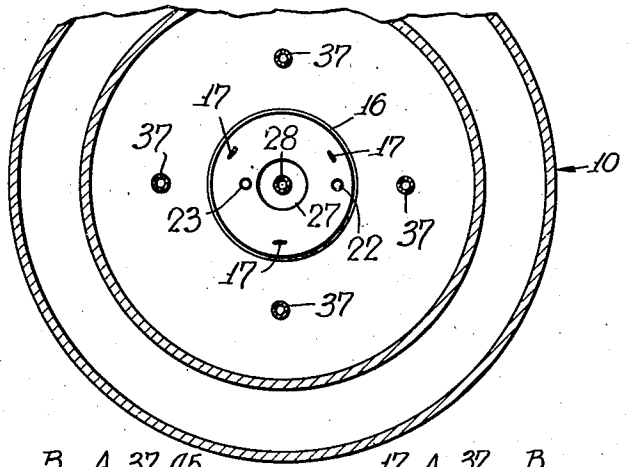
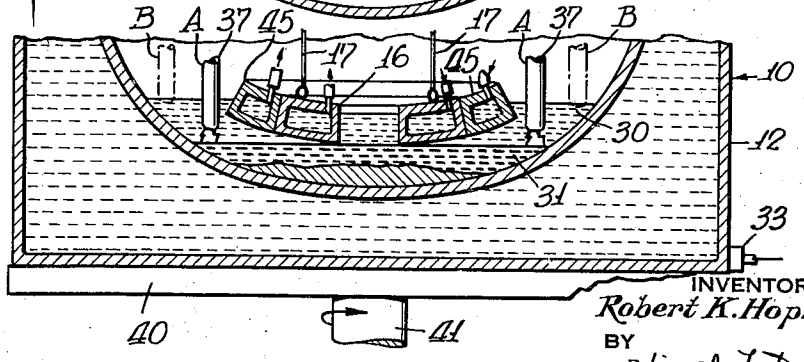


Fig. 3.



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Fig. 4.

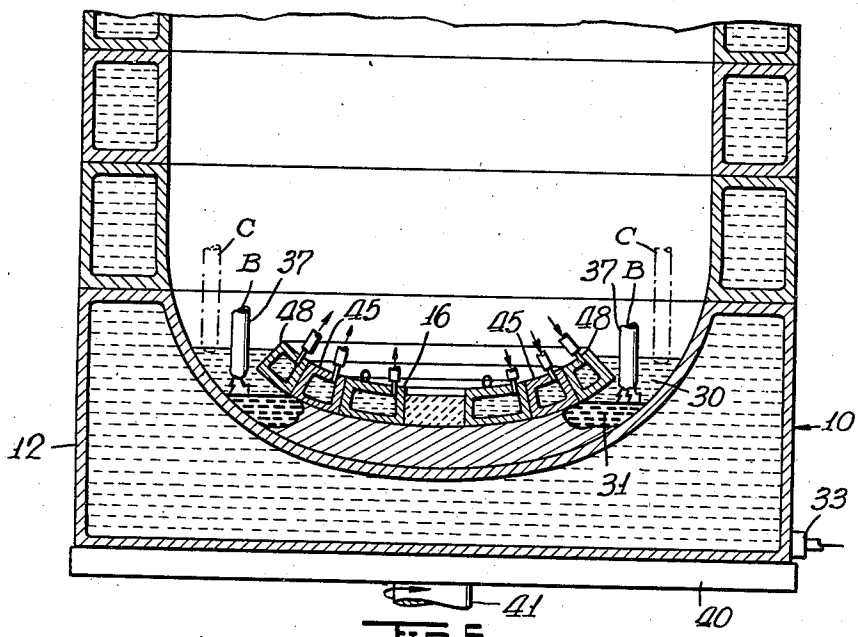
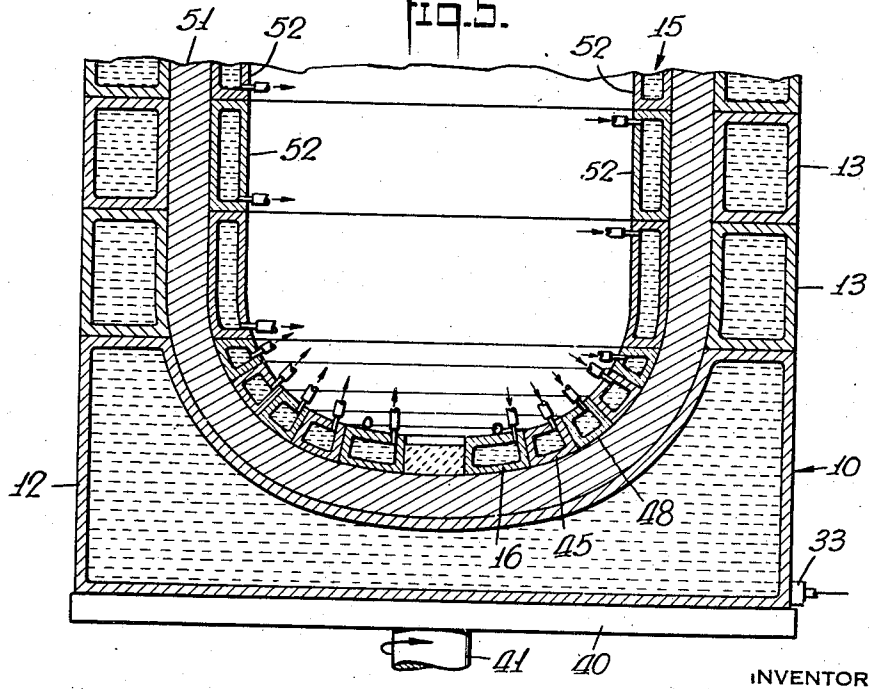


Fig. 5.



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METHOD FOR CASTING METAL

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10 Claims. (Cl. 22—200)

The present invention relates to a method for casting articles.

One object of the present invention is to provide a new and improved casting method.

Another object is to provide a new and improved method for casting a tubular article having a closed end.

A further object is to provide a new and improved method for casting a vessel or shell with a dished or convex head.

In the electric fusion process of making ingots, current is discharged across a flux submerged gap to create a metal fusing zone in and around said gap. At the same time, solid metal ingredients are fed into the fusing zone according to the desired analysis of the metal to be produced.

Another object of the present invention is to provide a new and improved method for casting articles according to the electric fusion process above described.

In accordance with certain aspects of the present invention, an outer mold is provided conforming to the outer shape of the shell or vessel to be cast, and having a bottom end wall. Metal is first produced and cast in the bottom of the outer mold by the electric fusion process above described. As the casting metal is produced and deposited in the outer mold, the inner mold of the shell to be cast is built up progressively from the center radially outwardly and upwardly by the use of mold sections or blocks. At the same time, the mold assembly is desirably rotated about a substantially vertical axis to equalize the distribution of the metal deposited in the mold space. In this manner, solidification of the metal deposited in the mold space and the composition of said metal can be effectively controlled to form a sound headed shell casting having the desired physical and metallurgical characteristics.

Various other objects, features and advantages of the invention will be apparent from the following particular description, and from an inspection of the accompanying drawings, in which:

Fig. 1 is a vertical diagrammatic section of a mold set-up for carrying out the initial stages of the casting method of the present invention;

Fig. 2 is a section of the mold set-up taken on line 2—2 of Fig. 1, but on a reduced scale; and

Figs. 3, 4 and 5 are vertical diagrammatic sections of the mold set-up similar to that of Fig. 1, but showing later successive stages respectively of the casting method of the present invention.

The invention is shown in the drawings applied to a method of making a tubular member with an end wall, and more specifically to a method of casting a vessel with a domed or bowl-shaped end wall or head, such as a pressure vessel or autoclave. However, it must be understood, that as far as certain aspects of the invention are concerned, this invention is applicable to the casting of articles of various shapes, especially symmetrical ones, and may be employed, as for example, in the manufacture of gun tubes, solid or hollow shafts and flanged articles such as manways.

Referring to the drawings, there is provided an outer mold 10, which conforms with the outer shape of the vessel to be cast, and which is shown with a bowl-shaped floor 11 defining the outer contour of the convex head or end wall of the vessel. This mold 10 is shown symmetrical with respect to the vertical axis and circular in internal cross-section. The contour of the mold floor 11 is shown substantially as a segment of a sphere, but as far as certain aspects of the invention are concerned, this contour may be of any desired configuration.

To permit repeated use of the mold 10, this mold is made of metal having high heat conductivity such as copper, and is hollowed to allow a suitable cooling medium such as water to be circulated therethrough. The mold 10 is advantageously sectionalized, and for that purpose is shown comprising a floor section 12 and separate wall sections 13 stacked on the sides of the floor section, and conjointly defining with the floor section a mold unit having the necessary internal casting form. Although the mold sections 12 and 13 are not shown with inlet and outlet connections for the circulating cooling liquid, it must be understood that these are provided and connected into the hollows of said sections in any suitable manner.

During the initial stages of the casting operation, the bottom center section 16 of the inner mold 15 defining the inner curved periphery of the vessel to be cast is disposed in casting position in the lower central part of the outer mold 10, and is spaced from the bottom of said outer mold by a distance corresponding to the thickness of the vessel head to be cast. This inner mold section 16 may be supported in casting position in the interior of the outer mold 10 in any suitable manner, as for example by a series of wires or cables 17, and is shown provided with an outer casting surface 18 extending substantially parallel to or concentric with the mold floor 11. However, in

accordance with certain aspects of the present invention, this outer casting surface may directionally vary with respect to the surface of the mold floor 11, to produce a head or end wall of varying thickness on the vessel to be cast.

The inner mold section 16 is desirably made of a construction which will permit its repeated use. For that purpose, this inner mold section 16 is made of metal having high heat conductivity such as copper, and is hollowed to permit circulation of a cooling medium such as water therethrough. Inlet and outlet connections 22 and 23 on this inner mold section 16 are connected to inlet and outlet manifolds 24 and 25 respectively, desirably through flexible hose connections.

Although the inner mold section 16 is shown as made of one annular piece, this mold section may be made into segments which are bolted or otherwise fastened together to form a single annular unit. Such fastening means should not be disposed in any position which will destroy the continuity of the lower mold surface 18 or the outer peripheral surface of the mold section 16.

For producing and depositing casting metal of the desired analysis in the interior of the outer mold 10, the inner mold section 16 is provided with a central aperture 27 in which centrally extends a consumable electrode 28. Electrode 28 has its lower end submerged in a layer of flux 30, and is spaced at this end from the molten deposited metal 31 by a flux submerged gap 32 through which electric current is discharged to create a metal fusing zone in and around said gap. To produce the necessary current discharge across the gap 32, the electrode 28 and the mold deposited casting metal 31 are connected in the same circuit. The necessary electrical connection to the deposited casting metal 31 can be effected through the metal walls of the outer mold 10, as for example, through a stationary brush contact 33.

The electrode 28 contains at least some of the ingredients of the casting metal to be produced. Other ingredients may be fed in granular, pellet or pulverulent form into the metal fusing zone created in and around gap 32. For feeding the fluent metal ingredients into the metal fusing zone, electrode 28 may be tubular, and the ingredients may be fed into the fusion zone through the hollow of the electrode. Electrode 28 may be continuously formed from a skelp as it is being consumed.

As the electrode metal is consumed, the electrode 28 is fed downwardly by any suitable means, indicated diagrammatically by the feed rolls 34, to maintain the gap 32 substantially constant in length.

The flux layer 30 floats out impurities in the metal and conserves the heat in said metal. This flux layer 30 may be of any suitable composition well-known in the metallurgical art, and may, for example, comprise silicates or components of silicates, such as magnesium silicate, calcium silicate, aluminum silicate or glass.

Since the metal producing operation is initiated with the electrode 28 close to the bottom of the outer mold 10 during the first stages of operation, and since the metal 31 produced and deposited in the outer mold gradually rises during the operation, it is necessary to move the electrode upwardly to keep it spaced from the rising level of metal 31. The downward feeding of the electrode 28 as it is consumed, and the upward movement of said electrode to compensate for rise in the level of the deposited metal 31 are correlated to maintain the current discharge gap 32 substantially constant in length. The upward movement of the electrode 28 may be effected by mounting said electrode with its feeding means on a suitable carriage 36 movable vertically, as for example, through cables or feed screws (not shown).

While metal is being produced and deposited in the center of the inner mold 10 through the electrode 28, any number of other electrodes 37 may be employed (four being shown) on the outside of said inner mold section according to the size of the vessel to be produced. These outer electrodes 37 may have their lower ends submerged in the flux 30, and operate in conjunction with fluent metal ingredients as does the center electrode 28, to produce and deposit metal on the outside of the inner mold section 16.

As the metal is being produced and deposited in the outer mold 10 in the manner indicated, mold 10 and the inner mold section 16 are slowly rotated in unison with respect to the electrodes 37 in order to effect even distribution of the deposited metal in said outer mold. The mold assembly may be rotated in any suitable manner. For example, it may be supported on a platform 40 which is secured to a vertical shaft 41 driven through a worm and worm wheel drive (not shown). The manifolds 24 and 25 of the water circulating system are advantageously arranged axially of the mold 11 to rotate with said mold.

After the metal 31 produced and deposited in the outer mold 10 reaches the level of the lower part of the inner mold section 16 as shown in Fig. 1, or the lower outer annular corner of said mold section, the metal producing operation of the center electrode 28 is discontinued. A second outer mold section 45 of hollow copper construction is then disposed in the outer mold 10 in position to form a continuation of the center inner mold section 16, and is connected to the manifolds 24 and 25 of the water circulating system through appropriate hose connections. While the second mold section 45 is being set in casting position, the metal producing operation of the electrodes 37 may be temporarily discontinued, but it is desirable to have their operation continue during this mold assembly phase as long as they are positioned away from the first inner mold section 16 by a distance sufficiently great to permit the second inner mold section 45 to be lowered easily into proper casting position without interference from said electrodes 37.

The inner mold section 45 is annular in shape, and fits snugly around the center mold section 16. The outer peripheral surface of the center mold section 16 is desirably inclined or conical, and the inner periphery of the second outer mold section 45 is of corresponding conical configuration to mate snugly with said outer peripheral mold surface. The second inner mold section 45 will thereby seat snugly over and around the first inner mold section 16, and will be retained in fixed casting position shown in Fig. 3 by the inclined or conical interengaging surfaces of said mold sections, so that no additional support for the second mold section is necessary.

With the second mold section 45 supported in casting position shown in Fig. 3, the outer electrodes 37 with their lower ends flux submerged are made to continue or resume their metal producing and depositing operations in the manner described. At the same time, these electrodes 37 are moved from the position A close to the outer periphery of the second mold section 45 radially

outwardly to an approximate position B close to and on the outer side of the prospective position of the third inner mold section 48 to be later added to the inner mold assembly. While the electrodes 37 are moved radially outwardly, they are also moved upwardly to keep apace with the rising level of the deposited metal 31, so that the current discharge flux submerged gaps below said electrodes respectively are maintained substantially constant in length.

When the deposited metal 31 reaches the lower outer annular corner of the second inner mold section 45, the third inner annular mold section 48 of hollow copper construction is added to the inner mold assembly as shown in Fig. 4, and in a manner similar to that described in connection with the addition of the second mold section 45, and said mold section 48 is connected to the manifolds 24 and 25 of the water circulating system through appropriate hose connections. During this mold assembly stage, the metal producing operations of the electrodes 37 may be temporarily discontinued, but these operations are desirably continued as long as enough space is available to set the third inner mold section 48 into proper casting position without interfering with said operations.

By the time the third inner mold section 48 is ready to be set into casting position, the portion of the deposited metal 31 underneath the first inner mold section 16 may be solidified, so that the cable supports 17 for said mold section may be dispensed with.

After the third inner mold section 48 has been set into proper casting position, the metal producing operations of the electrodes 37 are continued or resumed, and said electrodes are moved upwardly and radially from the position B to the approximate position C shown in Fig. 4 in a manner and for the purpose similar to that already described in connection with the movement of these electrodes from position A to B shown in Fig. 3.

The two component movements of each electrode 37 radially and upwardly from position A to B shown in Fig. 3 may be made simultaneously, so that by the time the deposited metal 31 reaches the lower outer annular corner of the second inner mold section 45, these electrodes will be in position B. However, as far as certain aspects of the invention are concerned, the electrodes 37 may be moved only vertically from the position A, while the first and second inner mold section 16 and 45 alone are set in casting position, and then after the deposited metal 31 has reached the lower outer annular corner of the second inner mold section 45, the elevated electrodes may be moved in one step radially outwardly to position B in preparation for the assembly attachment of the third inner mold section 48. Similarly, the electrodes 37 may be moved from position B to position C in two distinct steps during the phase of operation shown in Fig. 4.

If the movement of the electrodes 37 is effected simultaneously upwardly and radially outwardly, said electrodes are always maintained substantially midway of the horizontal width of the mold space between the outer and inner molds 10 and 15. If the electrodes 37 are moved step by step as described, the electrode positions A, B, C, etc., will be substantially midway of the horizontal width of the mold space.

After the deposited metal 31 reaches the lower annular corner of the third inner mold section 48, the operations referred to are repeated, and the progressive building of the inner mold 15 in stages concomitantly with the metal producing and depositing activities of the electrodes 37 continued as described and as shown in Fig. 5, until a vessel 51 of the desired shape has been cast. While the metal is being produced and deposited in the mold space, the molds 10 and 15 are rotated slowly as described, to assure uniform distribution of this metal in said space.

During the stages of the process when the cylindrical portion of the vessel 51 is being cast, the inner mold sections 52 for this portion are also cylindrical in shape, and are stacked one on top of the other. During this stage of the casting operation, the electrodes 37 are moved merely vertically in the mold space substantially midway between the sides thereof.

It should be noted that during the process of casting the shell 51 as described, a layer of highly superheated metal is continuously maintained in the upper section of the deposited metal. The highly superheated metal serves to feed the shrinking solidifying metal beneath it and thereby serves to continuously hot-top the metal as it is progressively cast. In this manner, a shell casting is produced which is sound and substantially homogeneous throughout its entire length.

As many changes can be made in the above method and apparatus, and many apparently widely different embodiments of this invention can be made without departing from the scope of the claims, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. A process of casting a vessel with an end wall, which comprises the steps of depositing molten metal in an outer mold having side and bottom walls, and progressively assembling an inner core in and correlatively to said outer mold from the center of said outer mold radially outwardly and upwardly as the level of the deposited metal rises, to form between the mold and the core a mold space defining the walls of the vessel to be cast, and to extend progressively said mold space radially ahead and above the rising level of the deposited metal.

2. A process of casting a vessel with a convex end wall, which comprises depositing molten metal in an outer mold having a cup-shaped mold cavity with a dished floor, and assembling an inner core in said outer mold step by step from the center of said outer mold radially outwardly and upwardly as the level of the deposited metal rises, to form with said outer mold a cup-shaped mold space dished at one end, and to extend progressively said mold space radially ahead and above the rising level of the deposited metal.

3. A process of casting a vessel with a convex end wall, which comprises assembling an inner core radially outwardly and upwardly in an outer mold having a cup-shaped cavity with a dished floor, to form with said outer mold a mold space conforming with the shape of the end wall of the vessel to be cast, and to extend progressively said mold space radially outwardly and upwardly, and depositing molten metal in said mold space through its outer extended section after each inner mold assembling step.

4. A process of casting, comprising producing and depositing molten metal in an outer cup-shaped mold by the current discharge action of one or more flux submerged electrodes, and pro-

gressively assembling an inner core in said outer mold correlatively with respect to said outer mold as the level of deposited metal increases, to extend the mold space defined between said molds progressively ahead of the deposited metal.

5. A process of making a vessel with a convex end wall, which comprises assembling an inner core radially outwardly and upwardly in an outer mold having a cup-shaped cavity with a dished floor, to form with said outer mold a mold space conforming with the shape of the end wall of the vessel to be cast, and to extend progressively said mold space radially outwardly and upwardly, and producing and depositing molten metal in said mold space after each inner core assembling step by the current discharge action of one or more flux submerged consumable electrodes extending in the outer extended peripheral section of said mold space.

6. A process of casting a hollow article, comprising depositing metal in a mold, assembling a core progressively and correlatively with respect to said mold as the amount of deposited molten metal increases, to extend progressively the mold space defined between said mold and said core ahead of the deposited metal, and rotating said mold and said core in unison as metal is being deposited in said space to effect substantially equal distribution of the deposited metal in said mold space.

7. A process of casting, comprising depositing molten metal in an outer cup-shaped mold, and progressively assembling an inner core in said outer mold correlatively with respect to said outer mold as the level of deposited metal increases, by adding annular core sections into snug peripheral embracing engagement with previously assembled inner annular core sections, whereby the mold space defined between said mold and core sections extends progressively ahead of the deposited metal.

8. A process of casting a vessel with a convex end wall, which comprises depositing molten metal in an outer cup-shaped mold with a dished curved floor, and as the level of deposited metal increases, progressively assembling an inner core in said outer mold by adding annular core sections into snug peripheral embracing engagement with previously assembled inner annular core sections, whereby the mold space defined between said mold and core sections extends progressively ahead of the deposited metal, said core sections having curved surfaces opposite said outer mold floor blending into one substantially continuous surface which extends substantially parallel to said outer mold floor.

9. A process of making a vessel with a convex end wall, which comprises depositing molten metal in a mold space between an outer mold and a partially completed inner core containing a peripheral annular section, adding an annular core section snugly around said last-mentioned annular core section when the molten metal in said space reaches a substantially predetermined level in said space, to extend progressively the mold space radially outwardly, and repeating said inner core assembling operation each time the level of the molten metal reaches a substantially predetermined level with respect to the last-assembled inner core section.

10. A process of making a vessel with a convex end wall, which comprises producing and depositing molten metal by the current discharge action of one or more flux submerged electrodes in a mold space between an outer mold and a partially completed inner liquid-cooled core containing a peripheral annular section, adding an annular liquid-cooled core section snugly around said last-mentioned annular core section when the molten metal in said space reaches a substantially predetermined level in said space, to extend progressively the mold space radially outwardly, repeating said inner core assembling operation each time the level of the molten metal reaches a substantially predetermined level with respect to the last-assembled inner core section, and rotating said inner core and outer mold while the metal is being produced and deposited in said mold space to effect substantially uniform distribution of the deposited metal in said space.

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