March 6, 1951 M. H. KALINA 2,544,598

METAL CASTING MOLD

Filed Feb. 28, 1948

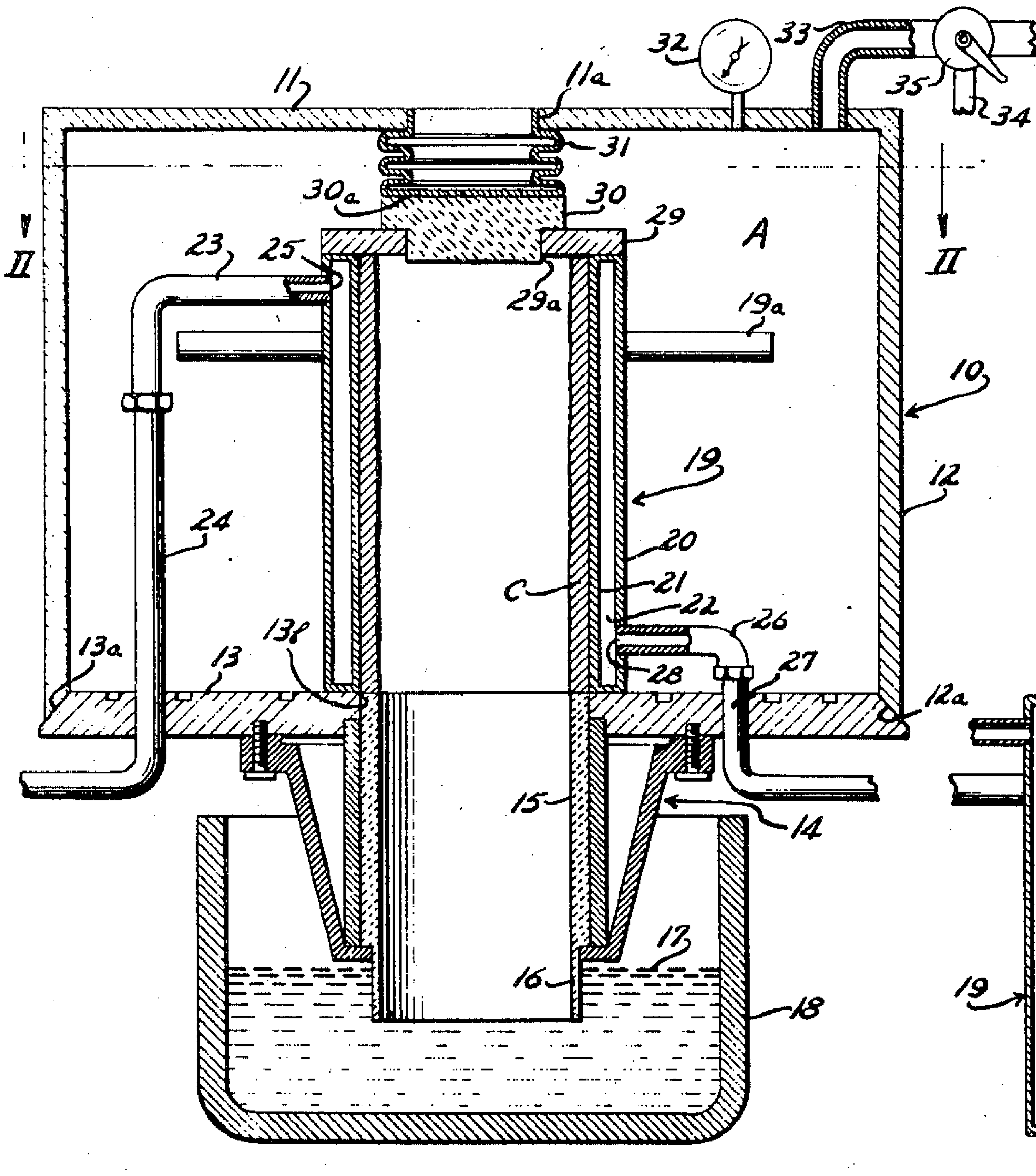

Fig. 1

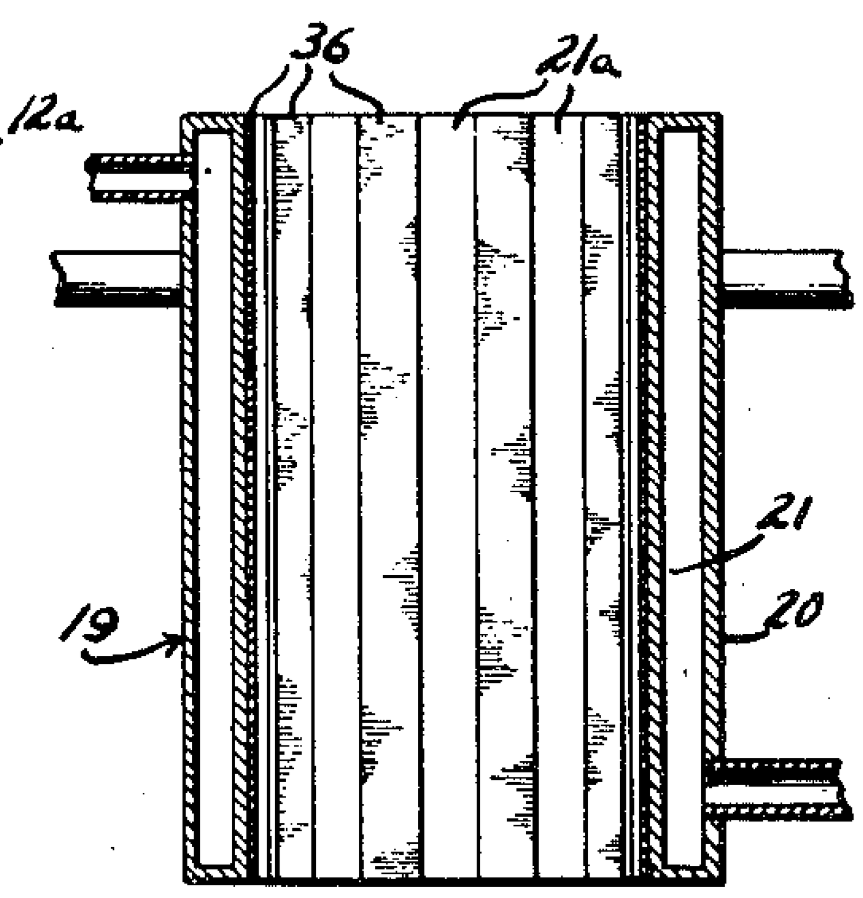

Fig. 3

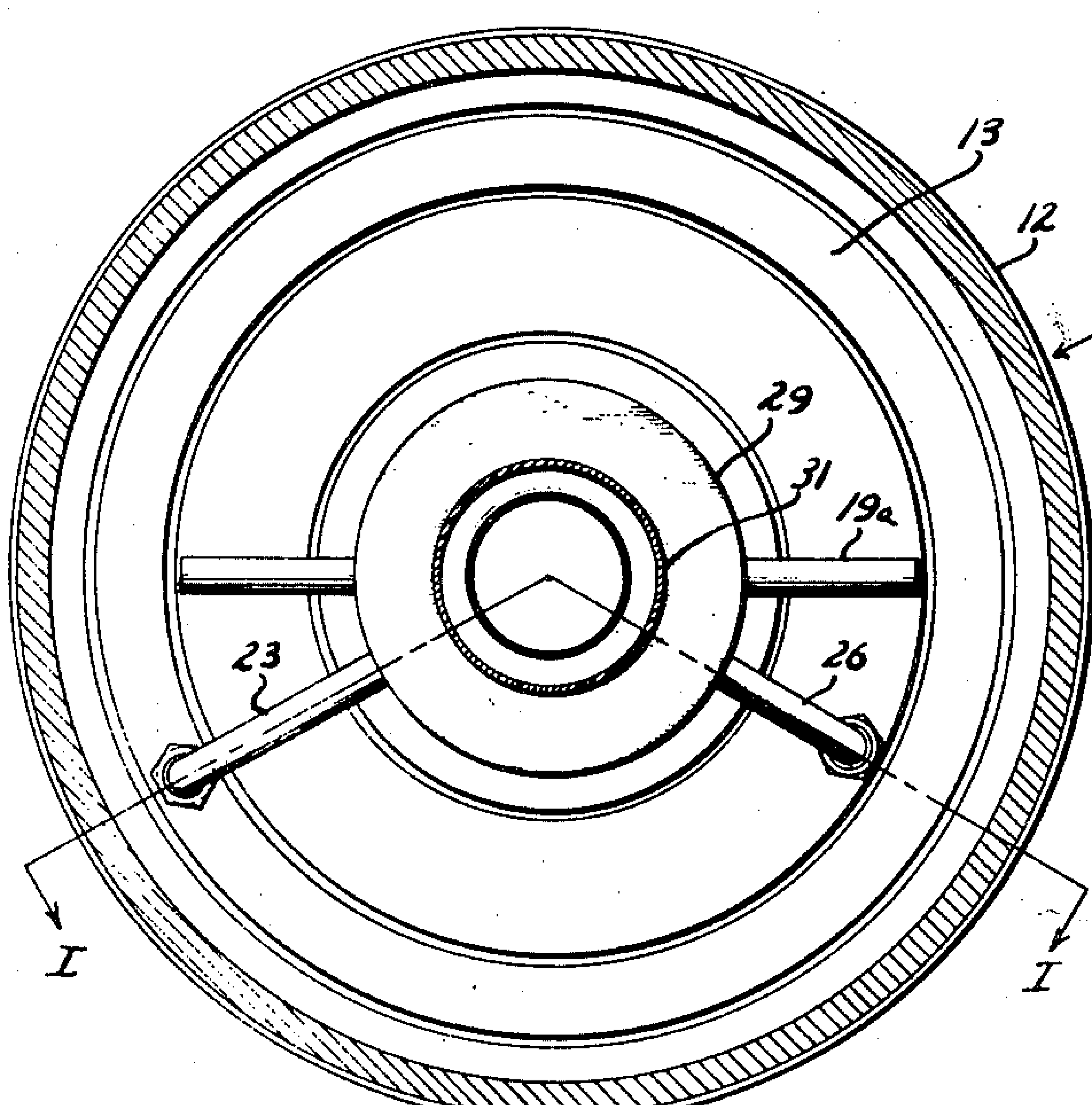

Fig. 2

Inventor
MARTIN H. KALINA

by The Firm of Charles W. Hills Attys.

Patented Mar. 6, 1951

2,544,598

UNITED STATES PATENT OFFICE

2,544,598

METAL CASTING MOLD

Martin H. Kalina, Gray, Saskatchewan, Canada, assignor, by mesne assignments, to Wetherill Engineering Company, Philadelphia, Pa., a corporation of Delaware

Application February 28, 1948, Serial No. 11,885

3 Claims. (Cl. 22—136)

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The present invention relates to a method of casting metal articles free of ingotism and to the product thereby obtained. More particularly, this invention relates to the casting of articles free of ingotism by counter-gravity casting methods, using metal molds.

In conventional methods of casting in permanent molds, the cast article is formed by the solidification of molten metal within a suitable metal mold or die. This molten metal, after having been introduced into the mold, solidifies inwardly from the wall surfaces of the mold perpendicularly to such walls. There is a tendency in the casting of ferrous metals, particularly in the early stages of solidification, for the growth of coarse, columnar, equiaxed crystals, usually dendritic in structure. This causes what is known in the art as "ingotism." Ingotism occurs in the casting of articles of any shape and is particularly evident in the casting of articles of angular shape having plane sides. Apparently in such castings, due to the uniform thermal characteristics of the chill walls, crystal growth is initiated and proceeds at a substantially equal rate inwardly of the surface of contact between the molten metal and the chill walls of the mold. The occurrence of ingotism may also be observed in the casting of cylindrical articles in which the lines of growth of the crystals tend to remain parallel to the axes of the initially formed crystals rather than to extend inwardly on truly radial lines from the outer periphery of the casting. As crystal growth proceeds, interference between adjacent groups of equiaxed crystals takes place and further inward crystal growth is retarded at points spaced circumferentially about the inner periphery of the solidified shell of the cylindrical casting. If the unsolidified, or molten, central portion of the casting is then removed, the result of the dendritic straight line freezing of the molten metal manifests itself by the polygonal, rather than cylindrical character of the inner surface of the hollow casting. The wall thickness of the various parts of the casting may vary as much as 35% with a corresponding variation in the strength of the casting when placed under stress. The strength of the casting is also adversely affected by the parallel growth of the metallic crystals, the casting being weakened along the surfaces of contact between adjacent groups of parallel crystals. Solid ingots, formed by the complete solidification of the molten metal within the mold, are also weakened by the parallel growth of the metallic crystals. The splitting and cracking of such ingots under stress in rolling may be attributed to ingotism.

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The present invention provides a method of casting solid or hollow metal articles free of ingotism. By the practice of the method herein described, ferrous or non-ferrous metals may be cast to any desired shape or form by the use of gravity or counter-gravity casting procedures. The method of the present invention is particularly applicable to the counter-gravity casting of hollow articles by the use of coreless metal molds. By the method of the present invention, ingotism, as produced by the dendritic straight line freezing of molten metal in a mold, is prevented by the use of metal molds having chill walls divided into alternate longitudinally extending areas having varying thermal characteristics. The varying heat conducting properties of the interior mold surfaces evidently causes a variation in the rate of crystalline growth during solidification of the molten metal. The actual mechanism of the crystallization in my casting process is not fully known at this time. However, it appears that crystals grow more rapidly from the more conductive areas of the chill walls, thus forming a plurality of groups of crystals extending radially inward from the outer periphery of the casting.

The rapid inward growth of the intially formed crystals results in the formation of a plurality of isolated groups of crystals spaced circumferentially about the inner chill walls of the mold. The spaces between adjacent groups of such crystals are filled by the crystals growing more slowly from the insulated portions of the chill walls. These more slowly growing crystals bind the groups of initially formed crystals into a solid, homogeneous mass relatively free from the effects of interference between adjacent groups of crystals. Thus, the castings prepared by the method of the present invention are free of ingotism caused by the dendritic straight line freezing of the molten metal. Thus, a hollow metal casting having uniform wall thickness, interior cavities corresponding closely to the configuration of the outer casting walls, and uniform behavior under stress may be obtained by the casting method herein described. The loss of strength due to interference between adjacent groups of crystals caused by the parallel growth of the crystals during the freezing of the molten metal is also avoided.

The casting method as herein described may employ apparatus similar to that described in my copending applications Serial No. 745,822, filed May 3, 1947, now abandoned and Serial No. 759,819, filed July 9, 1947, now Patent No. 2,515,654, issued July 18, 1950. The apparatus which I prefer to employ in the method of the present invention comprises a mold connected to a source of molten metal by means of a suitable mold gate. The chill walls of the mold may be made of metal or other suitable heat conductive material, but the top is closed centrally by a gas-permeable, non-chilling plug, preferably formed of sand or ceramic material. The chill walls of the mold are coated in spaced, longitudinally extending strips of silica or other compositions having thermal insulation properties. The mold may be employed in either gravity or counter-gravity methods of casting.

The method of the present invention, as applied to the counter-gravity casting of hollow articles and employing a mold such as that above described, may be briefly described as follows: The mold, mounted in a vacuum chamber, is connected by a gate to a suitable source of molten metal exposed to atmospheric pressure. The vacuum chamber is next evacuated, the mold being simultaneously evacuated due to the gas pervious top connection of the mold with the vacuum chamber. The molten metal is forced by exterior atmospheric pressure into the evacuated mold, the molten metal assuming the configuration of the mold. The molten metal is held in the mold until it solidifies along the chill walls of the mold. The solidification of the molten metal within the mold, due to the presence of the insulating strips on the chill walls, results in the formation of a casting free of ingotism caused by dendritic straight line freezing of the molten metal. Thus the method of the present invention provides a hollow casting having a cavity corresponding closely to the configuration of the outer casting wall.

When the metal has solidified to form cast walls of the desired thickness, the vacuum chamber is restored to atmospheric pressure. As the pressure in the vacuum chamber and in the mold increases, the metal in the mold which is not solidified is returned by gravity to its source. The mold is then removed from the vacuum chamber, and the hollow casting cooled and subsequently removed therefrom.

It is, therefore, an important object of the present invention to provide a method for the casting of metal objects free of ingotism.

It is another important object of the present invention to provide cast metal articles free of ingotism.

It is a further important object of the present invention to provide a mold for the casting of metal articles free of ingotism, said mold having chill walls partially coated with thermal insulating material to form alternate, longitudinally extending relatively good heat conducting and heat insulating areas.

It is a still further important object of the present invention to provide a method of making hollow metal castings free of ingotism, which comprises the steps of mounting in a vacuum chamber a mold having a top wall portion formed of gas pervious material and interior chill walls partially coated with an insulating material to form alternate longitudinally extending relatively conducting and insulating areas, connecting said mold to an exterior source of molten metal under atmospheric pressure, evacuating the chamber and hence the mold for a predetermined time to cause molten metal to fill the mold, said time being less than that required for the entire solidification of the metal so drawn into the mold, and then restoring atmospheric pressure in the chamber to cause still molten metal in the center of said mold to flow by gravity back into said source of molten metal.

Other and further important objects of the present invention will be apparent from the disclosures in the specification and the accompanying drawings.

On the drawings:

Figure 1 is a sectional view taken substantially along the broken line I—I of Figure 2, illustrating a preferred apparatus which may be employed in the method of the present invention;

Figure 2 is a sectional view taken along the line II—II of Figure 1; and

Figure 3 is a vertical sectional view of the mold employed in the method of the present invention.

In Figures 1 and 2, reference numeral 10 refers generally to a vacuum bell defining a vacuum chamber A. The vacuum bell 10 is cylindrical in shape having a closed upper end 11, a cylindrical side wall 12, and an open lower end. The lower edge of wall 12 slopes upwardly and inwardly to form an annular surface 12a. The vacuum bell 10 is removably mounted on base plate 13. The base plate 13 has an annular conical surface 13a formed around the periphery thereof, complementary to surface 12a of wall 12, thus forming a vacuum tight seal between the bell 10 and the plate 13 when the bell 10 is mounted thereon. A circular hole 13b is provided in the base plate 13 for a purpose to be hereinafter more fully explained.

Reference numeral 14 refers to a gate assembly, including a refractory gate portion 15. The gate assembly 14 registers with a circular hole 13b in the base plate 13. Said gate portion 15 has a lower projecting end 16 which is adapted to be submerged beneath the surface of molten metal 17 contained within a suitable container or ladle 18.

A mold or die, indicated generally at 19, is positioned over the hole 13b of base plate 13, the open lower end of the mold 19 registering with the hole 13b.

The double walled mold 19 is composed of an outer wall 20 and an inner or chill wall 21, the two walls defining an annular space 22 therebetween. Handles 19a are attached to the mold 19 for convenient handling of the mold 19. Inlet pipe 26, connected to a suitable source of water by a water line 27, communicates with the space 22 through port 28. Outlet pipe 23, connected to a suitable outlet line 24 communicates with space 22 through port 25. Both inlet line 23 and outlet line 26 enter the chamber A through the base plate 13. An annular cover plate 29, of substantially the same diameter as outer wall 20, rests upon the upper end of the mold 19 to overlie both the outer wall 20 and the inner wall 21.

A cylindrical vent plug 30, made of porous material, is fitted into the hole 29a in the center of the cover plate 29. The upper surface 30a of the plug 30 abuts the lower surface of a bellows-type pressure exerting member 31. The pressure exerting member 31 is fitted in a hole 11a centrally located in the upper wall 11 of the vacuum bell 10 so as to be subject to atmospheric pressure. The device 31 holds the mold 19 tightly against the upper surface of base plate 13 with the open lower end of mold 19 registering with hole 13b. A pressure gage 32 is provided in the upper wall 11 along with a pipe 33 which may be attached to a suitable evactuating apparatus, not shown, by means of which chamber A may be evacuated. A vent 34 to the atmosphere may be provided in the pipe 33 by means of a 3-way valve 35.

As shown in Figure 3, the interior surface 21a of inner wall 21 of mold 19 is partially coated with a non-metallic insulating material. As illustrated, the insulating coating applied to the inner wall 21a may be in the form of strips 36. It is preferred that the strips 36 be applied to the chill wall surface 21a to provide longitudinally extending insulating strips so that the inner surface of the mold may be uniformly divided into insulated and non-insulated portions. The strips 36 may suitably be from ¼" to 1½" in width, depending upon the diameter of the mold, and preferably equi-spaced circumferentially. In forming the strips 36 any suitable insulating material in combination with a suitable binding material, for example, a mixture of silica, graphite and pitch, may be applied to the mold as a liquid and then allowed to dry. Other heat insulating materials may be used for coating the inner surface of the mold, such as magnesia, chalk, talc, lime, refractory cements, diatomaceous earth, fire clay, "water glass," lamp black, and the like. The coating may be effected by spraying or brushing a liquid or pasty mixture of the insulating ingredients onto the interior mold surface in the desired longitudinal pattern and allowing the liquid or mixture to dry. It is not necessary to reapply the strips 36 after each use of the mold 19, since the strips 36 will remain intact after several casting cycles.

More particularly, it has been found that aqueous slurries of heat insulating materials such as silica flour bentonite, plumbago, magnesite and zircon flour may be employed for coating the inner surface of the mold. For example a thick slurry of any of the following compositions in water may be employed:

Composition No.	Constituent	Per Cent by Weight of Constituent
I	Silica flour	91
	Bentonite	7
	Sodium chloride	2
II	Silica flour	89
	Bentonite	2
	Clay	9
III	Silica flour	87
	Chrome ore	10
	Dextrin	3
IV	Silica flour	87
	Core oil (linoil)	1
	Bentonite	[illegible]
V	Silica flour	[illegible]
	Resin	4
	Bentonite	10
VI	Plumbago	62
	Bentonite	15
	Talc	15
	Solubilized starch	8
VII	Silica flour	95
	Resin	5
VIII	Magnesite	72
	Solubilized starch	14
	Bentonite	14
IX	Zircon flour	95
	Bentonite	2.5
	Core oil	2.5
X	Silica	95
	"Water glass"	5

It is desirable to add a suitable wetting agent to the slurry to enhance the spreading qualities of the slurry and to aid in the coating of the mold wall surface. I have found that a solution of soap in water added to the slurry serves as a satisfactory wetting agent, while aqueous solutions of other wetting agents or detergents such as the Gardinols or Avirols may be employed. The Gardinols and Avirols are alkali metal sulfates

of higher alcohols such as lauryl, myristyl, palmityl and stearyl alcohols.

As an example of a preferred heat insulating slurry the following composition is given:

Component	Per cent by Weight
Silica flour	41
Core oil (linoil)	6
Bentonite	3
Water	50
Total	100

A soap solution containing 6 ounces of water and 2 ounces of soap may be added to the coating composition to serve as a wetting agent. The interior wall surfaces of a mold such as mold 21 of Figure 3, were coated with the above identified composition to provide alternate longitudinal strips of relatively insulating and conducting material, as previously described.

According to the method of the present invention, the lower extremity 16 of the gate core 15 is inserted into the source of molten metal 17 in the container 18. The pipe fitting 33 is attached to a suitable evacuation apparatus and the chamber A is evacuated thereby. Water is circulated through the annular space 22 by means of inlet pipe 26 and outlet pipe 23. The mold 19 is evacuated of the gases contained therein through the vent core 30, which allows the passage of the gas from the mold 19 to the chamber A. As the mold 19 is evacuated, the metal 17 is forced through the gate portion 15 by the atmospheric pressure upon the molten metal 17 in the container 18. As the molten metal 17 rises in the mold 19 the molten metal assumes the configuration of the inner wall 21 of the mold 19. The degree of vacuum in the vacuum chamber A is indicated by the gage 32 and the vacuum may be regulated by a suitable adjustment of the evacuating apparatus.

The temperature of the molten metal at the start of the casting cycle is sufficiently high and the cooling rate in the mold sufficiently slow that the mold is entirely filled before substantial solidification occurs. The top surface of the metal as it reaches the under surface of plug 30 is still molten and, due to the non-chilling character of the plug, the surface remains molten after contact with the plug. The chamber A is maintained under vacuum until that portion of the metal which is adjacent to the chill wall 21 has solidified to form a casting of the desired wall thickness, such as indicated by the casting C, as shown in Figure 1. As hereinbefore explained, the dendritic straight line freezing of the molten metal is prevented by the strips 36 on the chill wall 21. After a sufficient amount of the molten metal has solidified to form the desired casting, the vacuum is shut off and the vacuum bell 10 is vented to the atmosphere by turning the valve 35. Contact between the molten metal 17 and the gate 15 may be broken, either by raising the vacuum bell, base plate and mold assembly or by lowering the ladle 18. Due to the permeability of the vent plug 30, the pressure on the upper surface of the still molten metal in contact therewith is increased accordingly, thereby causing all the molten metal in the central portion of the mold to drain by gravity from the mold 19 back into the ladle 18. Mold 19 may then be removed by lifting the vacuum bell 10 from its position on base plate 13 and removing the mold by means of the handle 19a provided thereon.

The method of the present invention has been described in detail as applicable to the production of hollow castings by counter-gravity casting methods. It will be appreciated that the method of this invention may be employed to produce solid castings such as ingots or bars of any desired cross-sectional configuration.

It will, of course, be understood that the various details of construction may be varied through a wide range without departing from the principles of this invention and it is, therefore, not the purpose to limit the patent granted hereon otherwise than necessitated by the scope of the appended claims.

I claim as my invention:

1. A mold for the casting of metal articles free of ingotism, said mold having a substantially cylindrical inner chill wall surface divided into a plurality of coextensive alternate, axially extending, relatively narrow strips of heat conducting and relatively heat insulating areas, said areas being defined respectively by said chill wall surface and by insulating coatings applied thereto, the number and width of said strips being such as to breakup radially inward straight line growth of dendritic crystals from the chill wall surfaces.

2. A mold for the counter-gravity casting of cylindrical hollow metal articles free of ingotism and having truly cylindrical central cavities, comprising an upper gas permeable closure wall, and side walls having a substantially cylindrical chill wall surface of heat conductive material, said chill wall surface being partially coated with insulating material so as to be divided into a plurality of narrow, axially extending, alternate heat conducting and relatively heat insulating strips defined by said chill walls and said insulating material applied thereto, said strips being substantially coextensive in length with the axial length of the side walls, and the number and width of said strips being such as to break-up straight line growth of dendritic crystals radially inwardly of the wall surfaces upon the solidification of molten metal in contact with said chill walls.

3. A mold for the casting of metal articles free of ingotism, said mold having interior chill walls composed of a plurality of alternate, axially extending narrow strips of heat conductive and relatively heat insulating material defined respectively by said chill wall surfaces and an insulating coating applied thereto, said coating being composed predominately of silica and containing a minor amount of a binder incorporated therein, and the number and width of said strips being such as to break-up straight line growth of dendritic crystals inwardly of the wall surfaces.

MARTIN H. KALINA.

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