United States Patent [19]

Kirby, Jr. et al.

[11] **3,760,864**

[45] **Sept. 25, 1973**

[54] **METHOD OF CASTING IN THIN-WALLED MOLDS**

[75] Inventors: **Russell B. Kirby, Jr.**, Baytown; **Stephen C. Wing**, Landfall; both of Minn.

[73] Assignee: **Minnesota Mining and Manufacturing Comapny**, St. Paul, Minn.

[22] Filed: **Feb. 12, 1971**

[21] Appl. No.: **114,800**

[52] **U.S. Cl.** **164/126**

[51] **Int. Cl.** **B22d 27/04**

[58] **Field of Search** .... 167/51, 113, 114, 167/117, 118, 119, 127, 284, 70, 244, 338, 361, 303, 312, 3 B, 316, 317, 125, 120, 123, 126, 128, 121, 305, 319

[56] **References Cited**

UNITED STATES PATENTS

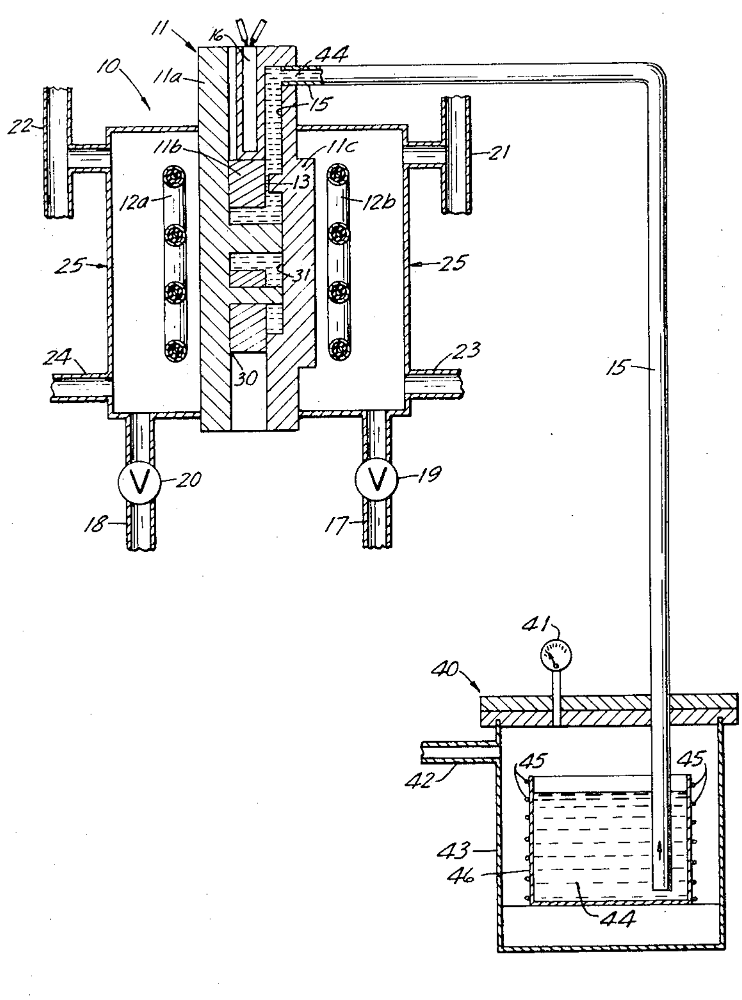
1,916,495	7/1933	Shaw	164/113 X
2,610,372	9/1952	Schroeder	164/312 UX
3,179,295	4/1965	Morin	164/303 UX
3,201,836	8/1965	Nyselius	164/312
3,596,708	8/1971	Lapin	164/312
3,472,308	10/1969	Lauth	164/123 X
2,782,476	2/1957	Brennan	164/126 X
3,373,793	3/1968	Smith	164/126 X
3,376,915	4/1968	Chandley	164/125 X
3,381,742	5/1968	Greenawald	164/125 X
3,620,289	11/1971	Phipps	164/60

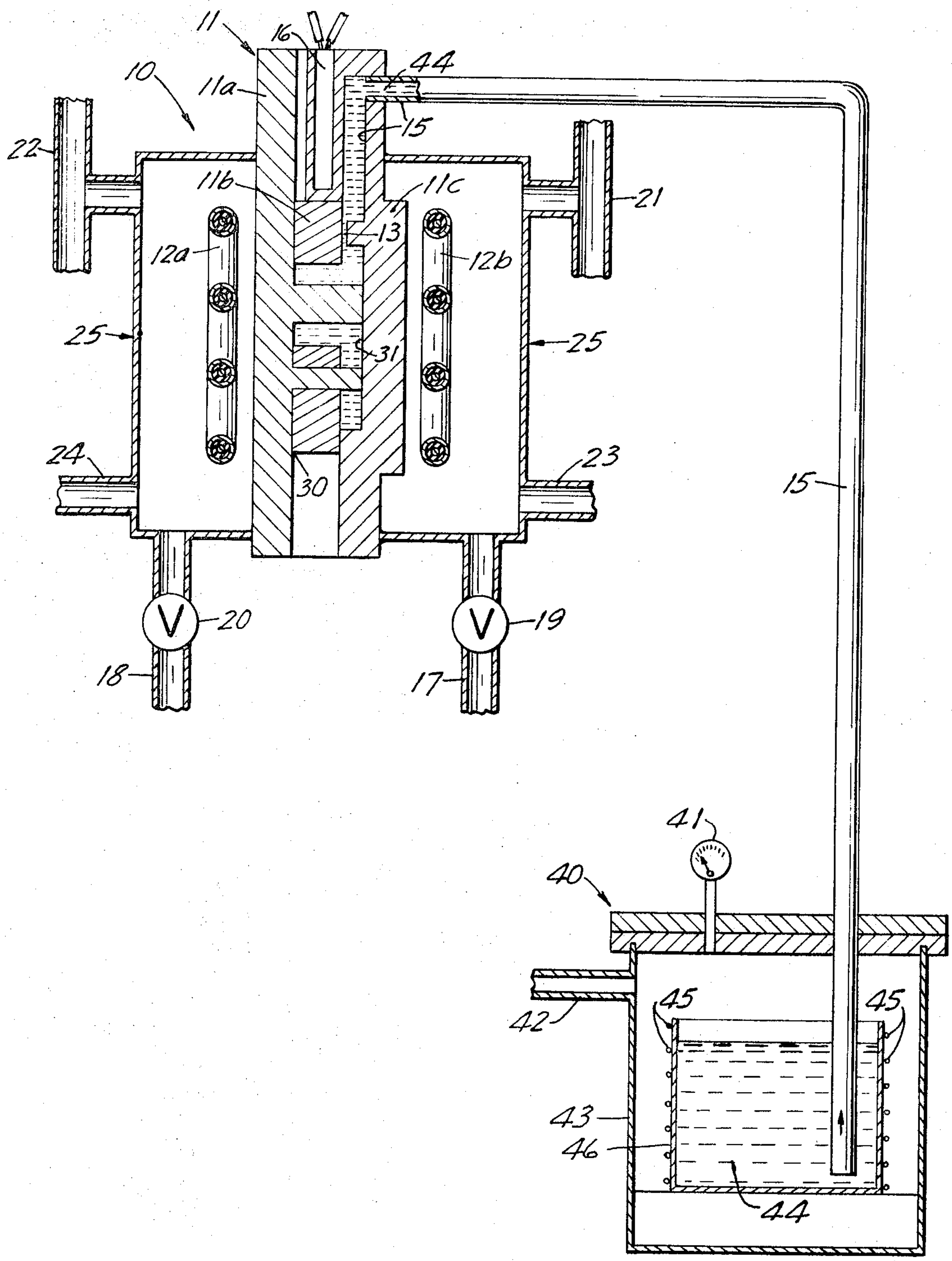
Primary Examiner—J. Spencer Overholser
Assistant Examiner—John S. Brown
Attorney—Kinney, Alexander, Sell, Steldt & Delahunt

[57] **ABSTRACT**

A thin-walled, highly heat conductive mold for casting low porosity metal articles having thin sections. The mold is perforate to provide a narrow gate opening preferably within the mold wall rather than along the mold parting line. In removing the articles from the mold the solidified metal in the gate opening breaks at its junction with the cast article to provide a gate-free article. A method is provided for producing, at a high production rate, the above-mentioned cast articles.

1 Claim, 1 Drawing Figure





INVENTORS
RUSSELL B. KIRBY, JR.
BY STEPHEN C. WING
Kinney, Alexander
Sell, Steldt & De La Hunt
ATTORNEYS

METHOD OF CASTING IN THIN-WALLED MOLDS

The invention relates generally to die casting, and it is particularly concerned with an apparatus and a method for forming low porosity metal articles having thin sections.

Die casting is a term used to designate the method of producing accurately dimensioned, sharply defined, smooth surfaced parts by forcing molten metal under pressure into a suitable permanent die or mold. High pressures, e.g., 1000 psi or more, are required to adequately fill the dies, therefore, the dies must be massive to withstand such pressure. These dies are rapidly cooled with each casting operation.

Die castings, i.e., the articles produced by such prior art methods are inherently porous, due to the manner in which molten metal is introduced into the die and rapidly cooled therein. Such porosity causes weaknesses in the articles. Additionally, heat treating porous castings causes voids therein to expand and create blisters which detract from the dimensional accuracy and the appearance of the articles.

Conventional die casting is limited in that it is not useful in preparing thin-walled articles having substantial surface area. These methods have been unable to produce such articles having thicknesses less than from about 25 to 30 mils. Attempts to produce articles with thinner sections have met with failure because the metal will freeze in the narrow cavity of the die casting mold before it is completely filled.

Improved casting methods which minimize porosity are known, but they are slow and are not suited for producing articles at a high production rate. One such method includes the step of progressively cooling the mold or die from a point farthest from the gate opening toward that opening. This manner of cooling is known as "directional cooling." For examples of such cooling see U.S. Pat. Nos. 1,876,073; 3,204,301; 3,381,742; and 3,248,764. The methods described in these references are slow because they depend upon complex cooling arrangements including the use of chill blocks or chill plates which require considerable time to cool.

Other deficiencies associated with the prior art metal casting methods include the production of cast articles having non-functional appendages thereon such as the cast counterpart of the runner of flash thereon which require time and man-hours to remove thereby increasing the production cost of each article. Flash is the cast leakage of molten metal through the opening between the mold parts. Flash is especially prominent in high pressure die casting wherein the high pressure forces metal through such an opening. Heretofore such non-functional metal appendages have been removed by cutting, grinding and/or polishing to provide the desired finished article.

The present apparatus and method produces cast metal articles which are substantially free of such appendages therefore they require little or no subsequent finishing. The molten metal is introduced into the mold under very slight pressure, e.g., 5 psi, thereby reducing the likelihood of flash. The molten metal is introduced through a very narrow gate opening or mold cavity feed line which is preferably not located at the mold parting line. This provides, upon solidification of the metal, a very narrow metal appendage which is easily broken off because of its small size, when the article is removed from the mold.

The instant invention has been utilized in connection with casting of molten conventional casting alloys to form parts having a wall thickness of approximately 0.005 inch throughout substantial surface areas, e.g., over areas of ten square inches or more. Such castings can be produced at a high production rate, e.g., at a rate of more than 300 castings per hour (in a single cavity mold).

The present apparatus and method, without the use of chill plates or the like, produce a directionally cooled article. Therefore the production of articles by the practice of the invention is not limited by the thermal inertia of such devices. A cooling fluid is applied to the desired portion of the mold to provide the directional cooling. The mold is thin-walled and highly heat conductive therefore the quenched portion cools rapidly causing the metal therein to solidify and cool in the desired direction toward the gate.

Another desired feature of the invention is provided by the narrow gate opening. Because of the location of the gate opening, molten metal therein solidifies thus acting as a valve to close the runner feeding molten metal to the mold cavity. The gate opening remains closed until the mold is reheated causing the metal in the gate to melt and permitting the metal to flow into the mold.

The present invention can best be understood and appreciated by reference to the accompanying drawing wherein:

The FIGURE shows in cross-section a casting apparatus according to the present invention.

The casting apparatus **10** is basically comprised of a mold **11** which is positioned within a high intensity heating means **12***a* and **12***b*, and this assembly being positioned within a cooling means **25.** Suitable control means is provided but not shown in the FIGURE to operate the heat source and the cooling means in a manner as hereinafter described. Such control means is provided by conventional devices as will hereinafter be described.

The mold is formed of at least two parts that are clamped or otherwise held together in a suitable manner to define a mold cavity which is the counterpart of the article being cast. In the present embodiment the mold **11** is made up of three parts **11***a*, **11***b*, **11***c*, which are held together to define cavity **31.** The mold can easily be opened and closed by mounting the mold parts on the ends of opposed hydraulic pistons or a suitable like device. The use of such devices for this purpose is known.

Molten metal is supplied under slight positive pressure to the mold cavity **31** through molten metal feed line **15** and gate opening **13** from a molten metal reservoir **40.** One of the mold parts is perforate to provide gate opening **13** which preferably does not permit molten metal to enter the cavity at the parting line **30** of the mold parts. Gate opening **13** is extremely narrow as compared to conventional casting systems. The small size of the gate opening has a two-fold function in the apparatus of the invention. First, a narrow gate opening produces a correspondingly narrow gate metal appendage on the article upon solidification. And because the gate opening in the preferred embodiment is not along the parting line of the mold, it is easily broken off the cast article at the surface thereof, as the article is ejected, providing an article which required no subsequent gate metal removal operations. The solidified gate metal in the gate opening serves the second function in that it acts as a valve stopping the flow of molten metal until the mold is reheated. Because the gate opening is narrow, only a small mass of metal is contained therein requiring but a brief amount of time to remelt the gate metal and start the flow of molten metal to the mold cavity. Thus the narrow gate eliminates the need for conventional valving systems which are often subject to failure in such use. To provide the abovementioned desired functions the gate should have a thickness within the range of from about 2 to about 20 mils, the preferred thickness being in the range of from about 5 to about 10 mils.

With such a narrow gate opening cooling of cast articles becomes critical. It is a well known phenomenon that molten metal will shrink upon solidification. Thus it is important to maintain open the gate opening to permit molten metal to enter the mold cavity as the metal solidifies. Allowing the gate opening to freeze closed before the article completely solidifies will produce spaces or voids in the article. Thus it is required to directionally cool, as hereinbefore described, in a manner which permits the gate metal to remain in the molten state until the article has solidified.

To facilitate rapid heating and cooling of the mold to open and close the gate opening, and the proper cooling of the mold to obtain the desired directional cooling, the mold has a thin wall and is constructed of a highly heat conductive metal. The mold wall thickness can be for example from ¼ inch to ¾ inch but this may be varied depending upon the size of the mold cavity and the capacity of the heating and cooling systems. To provide the desired heat properties the metal should have a thermal conductivity coefficient of at least 0.140 g. cal./(sec. cm.^{2})(°C/cm.). (The thermal conductivity coefficient is the quantity of heat in gram calories, transmitted per second through a plate of the metal one centimeter thick and one square centimeter in area where the temperature difference between the two sides of the plate is one degree Centrigrade.) The preferred metals for forming molds have a thermal conductivity coefficient of at least 0.300 g. cal./(sec. cm.^{2})(°C./cm.). Such metals permit rapid heating and cooling of the mold and its contents. It is further desired that the metals be able to withstand the corrosive action caused by repeated use of molten metals such as brass, aluminum, and other conventional casting metals. Exemplary metals having the abovementioned properties from which useful molds can be constructed include tungsten, molybdenum and mixtures of these metals. Such a mold can be formed by conventional metal forming methods such as machining as well as by well known powder metal technology methods wherein mixtures comprising metal powder and a heat fugitive binder are shaped to the desired form and sintered under the appropriate conditions to produce the desired mold.

The mold **11** is positioned with a high capacity heating means **12*a*** and **12*b*** which is spaced from the mold surface in fixed position to uniformly heat the mold walls. To produce the desired high production rate of cast articles the mold must be rapidly heated. For this purpose the heat source **12*a*** and **12*b*** must be able to produce at least 20 watts of heat per square centimeter of mold surface, preferably at least 30 watts per square centimeter. Such heat may be provided by direct resistance heating of the mold or by induction heating.

An auxilliary heater **16** may be provided, if desired, in the mold adjacent gate opening **13** to hasten the heating of solidified metal in these parts.

Cooling of the mold to give the desired directional cooling is accomplished by the use of a cooling means provided by liquid jacket **25** which surrounds the mold **11** and heat source **12**, having associated therewith liquid inlet lines **23** and **24**, liquid drain lines **17** and **18**, and liquid overflow lines **21** and **22**. After the mold cavity has been completely filled with the molten metal, liquid coolant is introduced through inlet lines **23** and **24** into the lower portion of jacket **25** to contact and cool the lower extremity of the mold. The liquid level is raised to cool the mold progressively toward the gate thereby permitting the gate to remain open until the metal in the mold cavity is solidified. If required, auxilliary heater **16** is activated to assist in preventing the solidification of the gate metal. Upon completion of cooling, valves **19** and **20** are activated to drain the liquid coolant from jacket **25**.

The molten metal reservoir **40** is comprised of a gastight housing **43** having connected thereto a pressure indicating device **41** and a gas inlet line **42**. The opposite end of gas line **42** is connected to a low pressure gas source such as a gas storage cylinder fitted with a regulator. Within housing **43** is a vessel **46** for containing molten metal **44**. Vessel **46** is heated above the melting temperature of the metal being cast by coils **45** wrapped thereabout or by some other suitable means. The end of runner or molten metal feed line **15** extends through the housing **43** in gas tight relationship and beneath the surface of the molten metal. A gas which is inert to the molten metal is applied through inlet **42** to the surface of the molten metal at a sufficient pressure to fill the mold cavity. Relatively low pressures are needed for this purpose such as would be sufficient to overcome the line resistance and the pressure head therein. Exemplary pressures would not exceed 50 psi and would generally be between about 5 to 10 psi. At such pressures little or no flash is produced. Alternatively, a metal reservoir situated above the mold cavity can be used, thereby permitting gravity to provide the necessary force for filling the mold cavity.

To form a cast article according to the present invention, the assembled mold **11** is pre-heated to a temperature at least equal to one half the melting temperature (expressed in degrees Celsius) of the metal being cast. Previously melted molten metal is forced from the reservoir **40** through a heated runner **15** into the mold cavity **31** until it is filled. The heat is cut back to a level which is capable of maintaining as a liquid the metal in the mold cavity **31**. A liquid coolant such as water is then introduced into the liquid jacket **25** at the portion thereof most distant from the gate opening through inlet lines **23** and **24**. The liquid coolant level is progressively moved in the jacket **25** until it is level with the gate. The induction heater is shut off upon solidification of the body of the article. This may be determined by monitoring the temperature of the mold with a suitable temperature indicating device. Upon achieving such solidification the jacket is drained, the mold is opened, and the part ejected, breaking the gate metal from the article at the article surface. The next metal article is prepared by closing the mold, heating the mold until the metal in the gate opening melts to permit the molten metal to flow, and repeating the abovementioned steps. The above described sequence of steps required to produce one article can be accomplished very rapidly, e.g., in as little as 0.2 minutes for an article having a wall thickness of from about 1/16 inch to about ⅛ inch.

It is, of course, to be understood that the foregoing description is illustrative only and that numerous changes can be made in the embodiment described without departing from the spirit of the invention as set forth in the claims.

What is claimed is:

1. A method for continuously producing at a high production rate low porosity metal castings requiring little or no subsequent finishing, comprising, repeating the following sequence of method steps:

heating, to a temperature sufficient to maintain molten the metal being cast, a thin-walled, thighly heat conductive, multi-part mold, the parts defining a mold cavity, one part being perforate to provide a narrow gate opening to said cavity,

while continuing said heating, completely filling said mold and said gate opening with the molten casting metal by introducing a continuous supply thereof under slight pressure into said cavity through said gate opening,

while maintaining said continuous supply of molten metal, contacting the exterior portion of said mold farthest distant from said gate opening with a liquid coolant,

progressively contacting the remainder of the exterior surface of said mold with said liquid coolant toward said gate opening to cause directional cooling and solidification of said molten casting metal, permitting complete filling of said mold during said solidification and the resultant contraction caused thereby,

continuing said cooling until the casting metal in said gate opening solidifies therein blocking said gate opening and temporarily terminating said continuous supply of molten metal,

removing said liquid coolant from contact with the surface of said mold, and

removing said solidified casting from said mold whereby causing fracture of the solidified gate metal from said article.

* * * * *