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Watts

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[54] **METAL CASTING PROCESSES WITH VACUUM AND PRESSURE**

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[58] **Field of Search**.....164/62, 65, 61, 255, 256, 258

[56] **References Cited**

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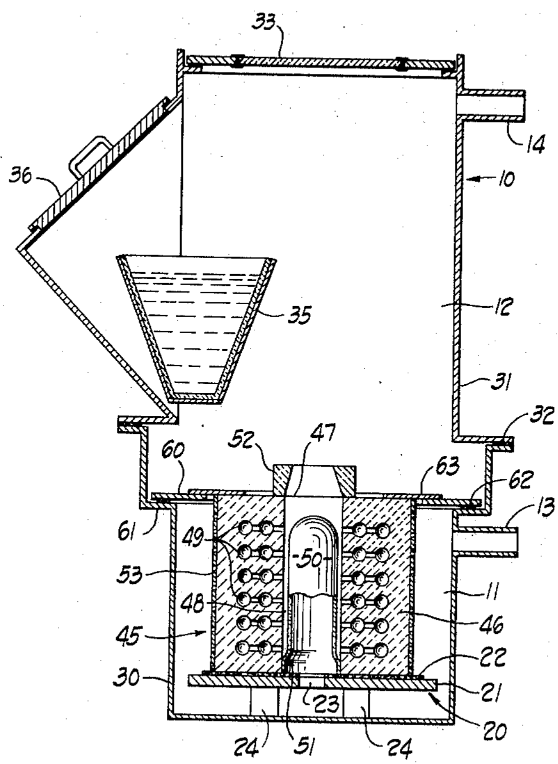
[57] **ABSTRACT**

A gas permeable mold, preferably an investment mold, is cast under a vacuum. The pressure on the molten metal exposed through the opening of the mold is raised to atmospheric pressure after casting, and a vacuum is applied to the outside of the mold during solidification of the metal.

12 Claims, 1 Drawing Figure



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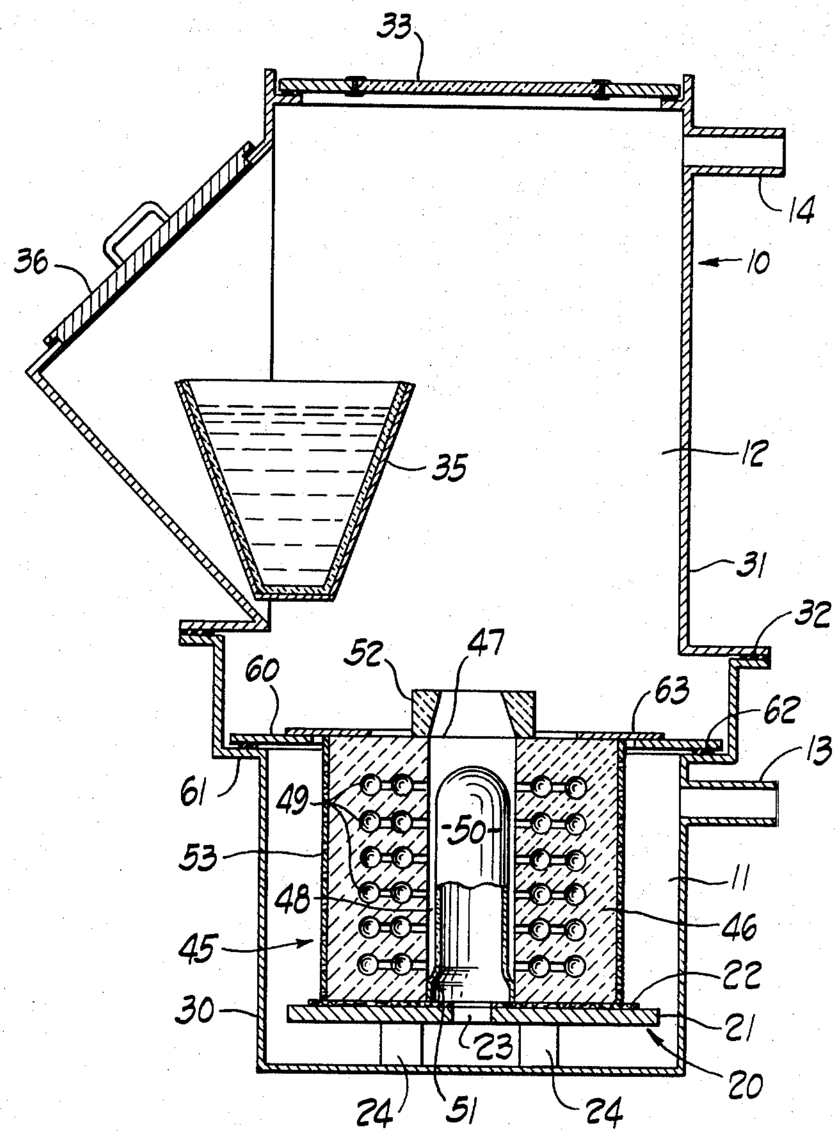

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METAL CASTING PROCESSES WITH VACUUM AND PRESSURE

BACKGROUND OF THE INVENTION

The present invention relates generally to metal casting processes, and more specifically to methods of casting investment molds, including both shell molds and bulk investment molds.

The invention is particularly concerned with providing methods for producing sound investment castings made of aluminum alloys and other metals which are subject to similar defects. Investment cast aluminum alloys are recognized to be especially susceptible to air entrapment and porosity, and in the past these conditions have been a major cause of rejected castings. In some instances, for example, when casting Type 355 and Type 356 aluminum alloys, a very high rejection rate of from 75 percent to 90 percent has been experienced. Another problem encountered in the investment casting of metals such as aluminum alloys is that of the metal retracting from the surfaces of the investment mold during solidification. This condition is frequently referred to as "draw-back."

SUMMARY OF THE INVENTION

According to the present invention, there is provided a method of casting a gas permeable mold, such as an investment mold, comprising the steps of introducing molten metal while under a vacuum into an opening of the mold to fill a cavity, thereafter increasing the pressure on the molten metal through the mold opening, and applying a vacuum to the outside of the mold during solidification of the metal.

According to a more preferred aspect of the present invention, there is provided a method of casting a gas permeable mold, such as an investment mold, which comprises the steps of placing the mold in a mold chamber so that the opening of the mold communicates with a vacuum casting chamber which is sealed from the mold chamber, evacuating the vacuum casting chamber and then introducing molten metal into the opening of the mold to fill a cavity, thereafter restoring the casting chamber to atmospheric pressure while the metal in the mold is still molten, and applying a vacuum to the outside of the mold by evacuating the mold chamber prior to solidification of the metal, and more preferably prior to introducing the metal into the mold.

The new methods provided by the invention can be used to cast many different kinds of metals, and may be found particularly advantageous in producing castings having thin wall sections. The new methods are especially suited for casting aluminum alloys and the like which are subject to air entrapment, porosity and draw-back.

Other advantages and a fuller understanding of the invention will be had from the following detailed description and the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

The drawing is a diagrammatical, vertical cross-sectional view showing an apparatus for carrying out the method of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The illustrated apparatus is the invention of Timothy L. Coghill and was developed after the date of the present invention. The apparatus is disclosed as the best known mode of practicing the invention, but no claim of inventorship is made thereto.

The illustrated apparatus comprises an enclosure **10** which is adapted to define a mold chamber **11** and a vacuum casting chamber **12**. The mold chamber **11** is connected through a conduit **13** and a valve (not shown) to a suitable vacuum source, such as a vacuum pump or line. The vacuum casting chamber **12** also is connected to a suitable vacuum source through a conduit **14** and a valve (not shown). The valves in the conduits **13, 14** are three-way valves which can be actuated to connect the chambers **11, 12** to vacuum source and to the atmosphere.

A platform **20** is provided within the chamber **11** for supporting a mold. The platform **20** may be comprised of a metal plate **21** on which is disposed a gasket **22**. Suitable gaskets may be made from asbestos pads, insulation or blankets formed of refractory fibers, such as aluminasilica fibers, and the like. A hole **23** is formed through the plate **21** and the gasket **22**, and the plate **21** is supported above the bottom of the chamber **11** by suitable supports **24**. The height of the supports **24** is preferably adjustable so that the top of the mold supported on the platform can be positioned in the desired plane.

As shown, the enclosure **10** includes a lower section **30** which defines the mold chamber **11** and an upper section **31** which defines the vacuum casting chamber **12**. A suitable sealing gasket **32** is provided between the two sections of the enclosure. The upper section **31** can be separated from the lower section **30** to permit a mold to be placed into and removed from the mold chamber **11**. The upper section **31** includes a window **33** through which an operator can observe the casting operation.

A ladle **35** is pivotally mounted in he casting chamber **12** for use in pouring metal into a mold supported on the platform **20** in the mold chamber **11**. A handle (not shown) which is used to tip the ladle extends through a side of the enclosure section **31**. The upper section **31** of the enclosure **10** is provided with a plate **36** which can be removed to fill the ladle **35**.

An illustrative investment mold which can be cast by the practice of this invention is generally designated by reference numeral **45**. The mold **45** is comprised of a refractory body **46** having an opening **47**, a central passage **48**, and a plurality of pattern cavities **49** which are gated into the passage **48**. As shown, a core **50** is positioned within the mold passage **48**. The core **50**, which may be formed of refractory material, has a closed end and an open end. A peripheral rim or step **51** is formed at the lower, open end of the core. The rim or step **51** serves to center the core **50** within the mold body **46** and substantially fills the passage **48** so that little or no molten metal can squeeze past the core when the mold is cast. A refractory pouring basin or collar **52** is shown positioned on the top of the mold **45** around its opening **47**.

The refractory mold body **46** may be made by conventional investment molding techniques. A plurality of patterns which are replicas of the parts to be cast in metal, including the necessary gates and risers, and which are formed of an expendable material, such as wax, are attached to a central sprue member to form what is known as a "set-up" or "tree." The set-up or tree is placed within a heat-resistant flask **53** which is preferably perforated and the flask is filled with a cementitious refractory material known as the "investment" which hardens at room temperature around the set-up or tree. The investment material may be a gypsum bonded refractory material which consists essentially of cristobalite and fine silica powder together with accelerators and retarders to adjust the setting time. After hardening, the set-up is removed from the mold body **46** to form the central passage **48** and the mold cavities **49**.

In carrying out the practice of this invention, the mold **45** is placed in the chamber **11** on the platform gasket **22** and the core **50** is positioned with its open end over the hole **23** of the platform. The mold chamber **11** is then sealed from the vacuum casting chamber **12** with the opening **47** of the mold in communication with the vacuum casting chamber. This is accomplished by a metal ring **60** which surrounds the upper end of the mold and is supported by a shoulder **61** of the lower enclosure portion **30**. A rubber sealing ring **62** or the like is disposed between the ring **60** and the shoulder **61**. The seal is completed by a ring **63** which rests on the upper end of the mold **45** and on the ring **60**. The ring **63** may be made of asbestos, rubber or other similar material.

When the mold **45** has been positioned in the manner described, the ladle **35** is filled with molten metal and a vacuum is drawn in the casting chamber **12** to evacuate the interior of the mold. In accordance with conventional practice, the metal is usually degased prior to being placed in the ladle, and therefore the metal can be introduced into the mold **45** as soon as the desired vacuum has been obtained in the chamber **12**. The degree of vacuum in the chamber **12** can be varied depending upon such factors as the kind of metal being cast, the amount of metal, the size of the mold, etc. A typical vacuum used for casting aluminum alloys is from **26** to **28** inches of mercury below atmospheric pressure.

After the molten metal has been poured into the mold **45**, the pressure in the casting chamber **12** is raised, preferably by relieving the vacuum and opening the chamber to atmospheric pressure. Atmospheric pressure on the molten metal exposed in the mold opening **47** acts to force the molten metal into the mold cavities to promote a complete fill and aids in preventing draw-back as the metal subsequently solidifies.

A vacuum is drawn in the mold chamber **11** prior to solidification of the metal and preferably at the same time that the vacuum is drawn in the casting chamber **12**. The metal in the mold opening is maintained at atmospheric pressure and the vacuum applied to the outside of the mold is continued during at least partial solidification of the metal. The degree of vacuum in the chamber **11** which has been found sufficient successfully to cast metals such as aluminum alloys is usually 15 inches or more of mercury below atmospheric pressure. It is believed that the effectiveness of the vacuum around the mold may be the result of removing air from the pores of the mold and thereby preventing any such air from coming out of the pores prior to and during solidification. Whatever the explanation, it has been found that the application of the vacuum to the outside of the mold while the metal is under pressure through the mold opening results in the production of sound castings which are free of the defects heretofore encountered.

The solidification characteristics of the metal are affected by the rate of cooling and the temperature of the molds at the time of introducing the metal. In order to promote a complete fill of the mold cavities, it may be desired to cast the molds while they are hot. For example, when casting Types 355 and 356 aluminum alloys, investment molds are frequently at a temperature in the range of from about 300° to 800°F., and preferably at a temperature of approximately 400°F. In other instances, for example, when producing castings having thick or heavy wall sections, it may be desirable to pour the molds at room temperature in order to chill the heavy wall sections as rapidly as possible.

An example of the invention involved the casting of an investment mold substantially as shown in the drawing, the mold having been made by the conventional practice described above. A dome-shaped core was spaced approximately one-half inch from the inside surface of the mold. The mold was cast at a temperature of 400°F. with Type 356 aluminum alloy which was poured at a temperature of 1,300°F. The nominal composition of the alloy was 0.3 percent magnesium, 7 percent silicon and the balance aluminum. A vacuum of 26 inches of mercury below atmospheric pressure was drawn in the casting chamber prior to introducing the metal into the mold. Immediately after casting the mold, the casting chamber was restored to atmospheric pressure and a vacuum of from 15 to 20 inches of mercury below atmospheric pressure was maintained in the mold chamber **11**. The metal was allowed to solidify for 2 to 3 minutes before releasing the vacuum in the mold chamber. The castings which were produced were found to be free of air entrapment and draw-back. Similar molds were cast with Type 356 aluminum alloy following the same procedure except for the elimination of the step of applying a vacuum to the mold body during solidification. The castings which were produced were unsatisfactory because of extreme porosity and severe drawback.

As used herein, the term "investment molds" is meant to include bulk or solid molds of the type shown in the drawing and ceramic shell molds. It is to be understood that the methods provided by this invention are not limited to the casting of investment molds of any specific type or which are made of a particular refractory material, and that the mold **45** has been disclosed only for the purpose of setting forth one specific example of the new casting technique. The methods which have been described may be used to advantage in casting bulk or solid type investment molds which are not provided with cores such as shown at **50**, ceramic shell molds, and other types of gas permeable molds, including sand molds, etc.

Many modifications and variations of the invention will be apparent to those skilled in the art in the light of the foregoing disclosure. Therefore, it should be understood that, within the scope of the appended claims, the invention can be practiced otherwise than as specifically shown and described.

What is claimed is:

1. In the casting of a gas permeable mold having an opening into which molten metal is poured to fill a cavity of the mold, a method comprising the steps of:
   a. evacuating the cavity of the mold and introducing molten metal while under a vacuum into the mold opening to fill the cavity,
   b. thereafter increasing the pressure on the molten metal through the mold opening, and
   c. Applying a vacuum to the outside of the mold prior to solidification of the metal.

2. In the casting of a gas permeable mold having an opening into which molten metal is introduced to fill a cavity of the mold, a method comprising the steps of:
   a. applying a vacuum to the opening of the mold,
   b. introducing molten metal under a vacuum into the mold opening to fill the cavity,
   c. thereafter relieving the vacuum applied to the mold opening so that the pressure on the molten metal in the mold is increased, and,
   d. applying a vacuum to the outside of the mold prior to solidification of the metal.

3. In the casting of a gas permeable mold having an opening into which molten metal is introduced to fill a cavity of the mold, a method comprising the steps of:
   a. removing air form the inside of the mold through the mold opening,
   b. introducing molten metal under a vacuum into the mold opening to fill the cavity,
   c. thereafter exposing the opening of the mold to atmospheric pressure while the metal is still molten,
   d. applying a vacuum to the outside of the mold prior to solidification of the metal, and
   e. maintaining the mold opening exposed to atmospheric pressure and continuing to apply a vacuum to the outside of the mold as the metal at least partially solidifies.

4. A method as claimed in claim 3 wherein the vacuum is applied to the outside of the mold prior to the step of introducing molten metal into the mold opening.

5. In the casting of a gas permeable mold having an opening into which molten metal is introduced to fill a cavity in the mold, a method comprising the steps of:
   a. mounting the mold so that its opening is in communication with a vacuum casting chamber,
   b. evacuating the chamber and then introducing molten metal into the mold opening to fill the cavity,
   c. increasing the pressure in the chamber while the metal in the mold is still molten,
   d. applying a vacuum to the outside of the mold prior to solidification of the metal, and,
   e. continuing the application of the vacuum as the metal at least partially solidifies.

6. A method as claimed in claim 5 wherein the vacuum is applied to the outside of the mold before introducing the molten metal into the mold opening.

7. In the casting of a gas permeable mold having an opening into which molten metal is introduced to fill a cavity of the mold, a method comprising the steps of:
   a. mounting the mold in a mold chamber with the opening of the mold communicating with a vacuum casting chamber which is sealed from the mold chamber,
   b. evacuating the vacuum casting chamber and then introducing molten metal into the mold opening to fill the cavity,
   c. thereafter restoring pressure to the vacuum casting chamber while the metal in the mold is still molten, and
   d. evacuating the mold chamber prior to solidification of the metal.

8. A method as claimed in claim 7 wherein the mold chamber is evacuated before the step of introducing the metal into the mold opening.

9. A method as claimed in claim 7 including the step of preheating the mold before placing it in the mold chamber.

10. In casting a gas permeable mold having an opening into which molten metal is introduced to fill a cavity of the mold, a method comprising the steps of:
   a. evacuating the cavity of the mold and introducing molten metal under vacuum into the mold opening to fill the cavity,
   b. thereafter causing the pressure on the molten metal which is exposed through the opening of the mold to be increased,
   c. providing a sealed chamber around the mold,
   d. evacuating the chamber to apply a vacuum to the outside of the mold before the metal in the mold cavity has solidified, and
   e. continuing to apply the vacuum to the outside of the mold and to maintain the increased pressure on the metal through the mold opening while the metal at least partially solidifies.

11. A method as claimed in claim 10 including the step of heating the mold so that it is hot during introduction of the molten metal.

12. In the casting of a gas permeable mold having an opening into which molten metal is introduced to fill a cavity of the mold, a method comprising the steps of:
   a. mounting the mold so that its opening is in communication with a vacuum casting chamber,
   b. evacuating the casting chamber and then introducing molten metal into the mold opening to fill the cavity,
   c. thereafter increasing the pressure on the metal in the mold through the mold opening,
   d. providing a sealed chamber around the mold,
   e. evacuating the sealed chamber to apply a vacuum on the outside of the mold before the metal in the mold cavity has solidified, and
   f. continuing to apply the vacuum to the outside of the mold and to maintain the increased pressure on the metal through the mold opening while the metal at least partially solidifies.

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