Jan. 28, 1969 C. H. WATTS ET AL 3,424,227

METHOD OF INVESTMENT CASTING

Filed May 4, 1966

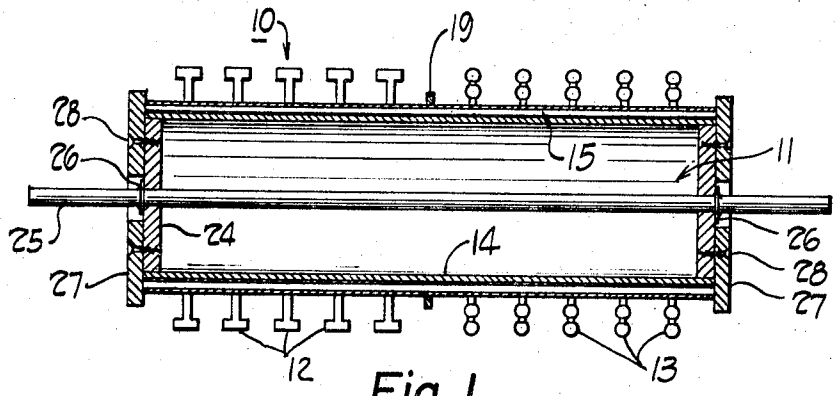


Fig. 1

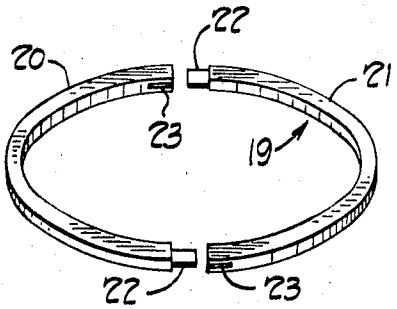


Fig. 2

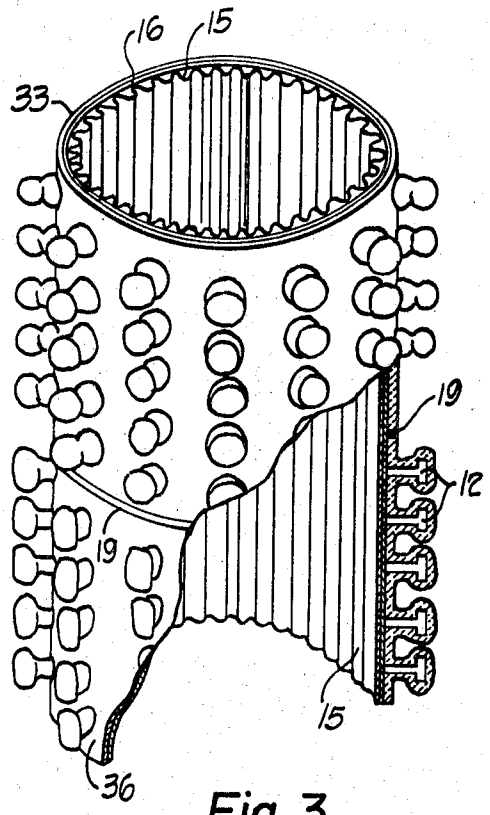


Fig. 3

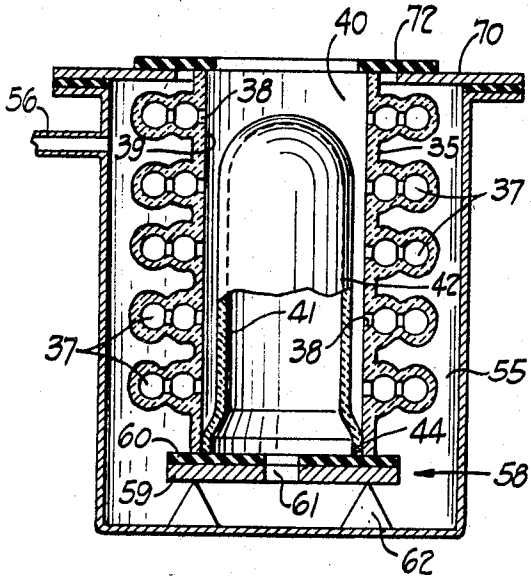


Fig. 4

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METHOD OF INVESTMENT CASTING

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ABSTRACT OF THE DISCLOSURE

In the art of investment casting, a process comprising the steps of forming a set-up including sprue means, divider means which projects from the outer surface of the sprue means around its perimeter and is located between the ends of the sprue means, and a plurality of laterally extending patterns attached to the sprue means on each side of the divider means, forming a refractory mold wall around the set-up at each side of the divider means, removing the set-up from the mold wall to provide separate refractory molds each having a through passage and a plurality of pattern cavities gated into the passage, and closing one end of each mold passage so that molten metal can be cast into the molds.

This invention relates generally to the art of investment casting, and more particularly to ceramic shell molding techniques of precision casting wherein shell molds suitable for casting metal are prepared by building up layers of refractory material around disposable patterns which are subsequently removed from the molds.

Ceramic shell molds are prepared using patterns which are replicas of the parts to be cast, including the necessary gates and risers, and which are formed of an expendable material, such as wax or a suitable synthetic resin or blends of wax and resin. These patterns are attached to a central sprue member to form what is known as a "set-up" or "tree." The formation of a shell mold around the tree or set-up is generally accomplished by applying a refractory slurry coating of controlled viscosity followed by directional draining to coat the patterns completely. After draining excess slurry from the set-up, the slurry coating is sanded or stuccoed while wet with coarser refractory materials. The result is a layer of ceramic material having refractory particles embedded in the surface. This layer is hardened, as by forced air drying at room temperature. After the first ceramic layer is sufficiently hard and dry, the steps of coating, draining, stuccoing and drying are repeated until a refractory shell having a sufficient thickness to resist the stresses occurring in subsequent operations has been built up around the set-up. In a subsequent pattern removal operation, the patterns are destroyed and the shell mold is prepared for the casting operation.

A recent development of significant importance in ceramic shell molding and investment molding techniques involves the concept of initially forming the one-piece refractory mold so that it has an open-ended, through axial passage and a plurality of pattern cavities gated into the passage. A core may be assembled in the mold passage after the pattern removal operation in order to form a tubular sprue and thereby obtain the advantages of directional solidification, a low ratio of gating metal to casting metal and improved metallurgical characteristics of the castings.

The formation of mold shells with through passages results in many economies and substantial improvements in all phases of ceramic shell molding operations, including the removal of the patterns. It is possible to cast more parts in each individual shell mold, and the molds can be made quicker and with fewer handling problems

than in the past. Because of the through passage in the mold, the patterns can be destroyed without cracking the relatively thin walls of shell molds and in a shorter time than when processing conventional shells. For example, when the patterns are formed of a heat expendable material, the mold can be quickly heated both internally and externally. The internal heating of the mold affords almost instantaneous relief for each pattern cavity gated into the open passage and thus prevents mold cracking due to detrimental pressures created by expansion of the pattern material during heating. The open ended passage formation also facilitates destruction of the patterns by solvent removal techniques and by the use of steam and pressure.

The purpose of the present invention is to provide a new investment molding process whereby a plurality of refractory molds each having a through passage and a plurality of pattern cavities gated into the passage are formed simultaneously using a single set-up or tree. The new process is particularly suited to ceramic shell molding techniques and makes it possible to obtain all of the economies of shells with through passages when producing small as well as large production orders.

According to one aspect of the present invention, there is provided a process comprising the step of forming a set-up including sprue means, a plurality of laterally extending patterns attached to the sprue means and a divider portion which projects laterally from the sprue means between its ends, the step of forming a refractory mold wall around the set-up at each side of the divider portion, the step of removing the set-up from within the mold wall to provide separate refractory molds each having a through passage and a plurality of pattern cavities gated into the passage, and the step of closing one end of each mold passage so that molten metal can be cast into the molds.

According to a more specific embodiment of the invention, there is provided a process of ceramic shell molding comprising the step of forming a set-up including a cylindrical sprue means, a divider portion which projects circumferentially from the sprue means between its ends and a plurality of laterally extending patterns attached to the sprue means, the step of forming ceramic shell sections around the set-up by applying refractory slurry coatings to the set-up except for the outer peripheral surface of the divider portion, stuccoing the slurry coatings with refractory particles and drying the stuccoed coatings, the step of removing the sprue means from within the shell sections to provide individual ceramic shell molds each having an open ended cylindrical passage therethrough, the step of destroying the patterns by circulating a pattern removal medium through the mold passages to form pattern cavities gated into the passages, and the steps of closing one end of each mold passage and placing a core in each passage in spaced relation to the inner mold surface.

The central sprue means which forms a part of the set-up used in the new process may comprise a cylinder, the divider portion being formed by providing a ring around the cylinder between its ends. Alternatively, it is contemplated that the sprue means of the set-up may comprise a plurality of axially aligned cylinders, the ends of which are separated by a circumferentially projecting disc or plate which serves as the divider portion. In the specific embodiment of the invention hereinafter described in detail, the sprue cylinder may comprise a tube, a corrugated cardboard sleeve around the tube and a wax coating on the outside of the sleeve.

The new process of forming a plurality of refractory molds by use of a single set-up has many advantages. One important advantage is that the production of a single set-up for a plurality of molds is quicker and more

economical than the conventional practice of making a separate set-up for each mold.

Another important advantage is that the time, equipment and handling problems heretofore involved in the production of ceramic shell molds are materially decreased. In the conventional ceramic shell molding process, each mold was made using a separate pattern tree or set-up and these set-ups were individually handled, either manually or by means of suitable apparatus, in the dipping, draining, stuccoing and drying operations. Since the process of the present invention makes it possible to handle only a single set-up in the shell-forming operations simultaneously to produce several molds, the mold production rates are increased.

As described above, the formation of a shell mold having a through passage is economical and a set-up of many patterns can be processed to form the mold. The practice of the present invention makes it possible to obtain the same economies when casting small production orders each of which may require different patterns and a different casting metal. Patterns for the different orders can be attached to a sprue to form a single set-up and the set-up processed to form a plurality of shells. After the set-up has been destroyed, these shells can be separately cast with the particular metal required for each order.

Other advantages and a fuller understanding of the invention will be had from the following detailed description when taken in conjunction with the accompanying drawings.

In the drawings:

FIGURE 1 is a cross-sectional view of an assembly including a preferred set-up or tree used in the process of this invention;

FIGURE 2 is a perspective view of a divider ring assembly used in conjunction with the set-up of FIG. 1;

FIGURE 3 is a perspective view showing a ceramic shell mold formed around the set-up of FIG. 1;

FIGURE 4 is a schematic, vertical cross-sectional view showing a ceramic shell mold and core assembly in an apparatus suitable for holding the mold assembly in position for a casting operation.

Referring now to the drawings, and to FIG. 1 in particular, the illustrated pattern assembly includes a set-up or tree which is generally designated by reference numeral **10**. The set-up **10** comprises a central sprue member **11** and two groups **12** and **13** of laterally extending patterns attached to the sprue member. The patterns, which are replicas of the parts to be cast and include the necessary gates and risers, are formed of an expendable material, such as wax or a synthetic resin or a wax and synthetic resin composition. The two groups of patterns **12** and **13** are shown as having a different shape in order clearly to illustrate that molds for different parts can be made by use of a single set-up. It is to be understood that more than two groups of patterns can be attached to the sprue member and that all of the patterns can be identical.

Preferably, the central sprue member **11** is in the form of a hollow cylinder and is comprised of a tube **14** made of cardboard or other relatively stiff material and a corrugated cardboard sleeve **15** which surrounds the tube **14**. As shown, the sleeve **15** is axially corrugated only in its inner surface while the outer wall surface of the sleeve is smooth. This preferred structure of the sleeve **15** is such that the tube **14** can be easily removed from the sleeve after the shell forming operations. The smooth outer cylindrical wall of the sleeve **15** is provided with a thin coating **16** of a low melting point wax. The wax can be coated on the sleeve **15** by rotating the tube and sleeve assembly on a horizontal axis in a molten wax bath. The thickness of the wax coating **16** which is formed is sufficient to permit the gate ends of the patterns **12** and **13** to be secured to the sprue member **11** by locally heating the wax coating and embedding the gate ends in the softened wax. Preferably, the thickness of the wax coating is in a range from about $\frac{1}{32}$ of an inch to about $\frac{1}{16}$ of an inch.

In alternate constructions, the sprue member **11** may be formed by an injection molded or extruded tube of wax or synthetic resin. The hollow, open-ended sprue member **11** also may be formed by a wax coated metal tube or the like.

In accordance with the present invention, the two groups of patterns **12** and **13** are separated by a divider portion **19** which forms part of the set-up **10**. As will become more apparent from the following description, the divider portion **19** facilitates the formation of separate refractory shells around the two groups of patterns. While only one divider portion is shown in FIG. 1, it is to be understood that a plurality of axially spaced dividers may be provided around the sprue member **11** in order to form as many separate shell molds as may be desired.

The illustrated divider portion **19** is in the form of a ring which projects radially from the sprue member **11** a distance which should be at least equal to the wall thickness of the mold to be formed. The wall thickness of a typical shell mold is in the range of from about $\frac{1}{8}$ of an inch to about $\frac{1}{4}$ of an inch. As best shown in FIG. 2, the preferred divider ring **19** may consist of two segments **20** and **21**. Each segment is conveniently provided with a tongue **22** at one end and a complemental slot **23** at the other end. In use the ring segments **20** and **21** are placed around the outside of the wax coated sleeve **15** in the desired position and the tongue **22** of one segment is fitted into the slot **23** of the other segment. The tongues **22** can be secured in the slots **23** in any suitable manner, such as by cement or, when the segments are formed of plastic, by softening the tongues with a solvent so that they are welded in the slots.

In order to facilitate handling of the set-up **10**, a disc **24** is fitted into each open end of the sprue member **11**. A rod **25** extends axially through the set-up **10** and the discs **24** are secured at **26** to the rod by any suitable means. The rod **25** may be provided with a handle (not shown) at one end or with a drive gear (also not shown), so that the set-up can be rotated during the shell-forming operations. The assembly shown in FIG. 1 is completed by annular plates **27** which are engaged against the ends of the set-up and are secured to the discs **24**, such as by screws **28**. The plates **27** project circumferentially beyond the sprue member **11** a sufficient distance to prevent the shell forming material from being built up around the ends of the set-up.

In carrying out the shell forming operations, the set-up **10** is coated a desired number of times with a refractory slurry in accordance with conventional practice. During application of the slurry coatings, the slurry may be removed from the outer peripheral surface of the divider ring **19** in order to form a separate coating at each side of the divider. After each application of slurry, the setup **10** is directionally drained to remove excess slurry and the wet coating is stuccoed with refractory particles. Each stuccoed coating is hardened, as by forced air drying, to form a refractory layer around the set-up **10**. This sequence of operations is repeated as many times as is necessary to build up a shell wall having the thickness and strength required for the particular casting operation. As noted above, the usual wall thickness of a shell mold is on the order of from about $\frac{1}{8}$ of an inch to about $\frac{1}{4}$ of an inch.

After the shell forming operations have been completed, the assembly of the tube **14**, the discs **24**, the rod **25** and the end plates **27** are removed from the invested set-up. Referring to FIG. 3, it will be seen that the mold wall formed around the sprue member **11** is circumferentially disrupted by the divider portion **19** to define two refractory shells **35** and **36**. When the corrugated sleeve **15** is subsequently stripped from the inside surfaces of

the shell sections, the sections separate to provide individual molds. Each mold is then subjected to a pattern removal operation, such as by placing the molds in a furnace or an autoclave, to destroy the patterns **12** and **13**.

Reference is now made to FIG. 4 which illustrates the final stage in the process of this invention. As here shown, the sprue **11** has been completely removed and the pattern material destroyed to form pattern cavities **37** in the shell **35**. The inside surface **39** of the shell **35** defines a cylindrical passage **40**, and the gate ends **38** of the cavities **37** open through the surface **39**.

A refractory core **41** may be provided within the shell **35** in spaced relation to the inner shell surface **39** to define a tubular sprue passage **42**. As shown, the core **41** is a hollow member having a closed dome-shaped end, an opposite open end and a peripheral rim or step **44** around the open end. The rim or step **44** serves to center the core within the shell and substantially fills the lower end of the sprue passageway **42** so that little or no molten metal can squeeze past the core when the mold is cast.

A suitable apparatus for use in casting the mold and core assembly is shown to be comprised of a vacuum and casting chamber **55**. The vacuum and casting chamber **55** is provided with an outlet pipe **56** which is connected through a suitable valve (not shown) to a vacuum pump or line. A platform **58** including a metal plate **59** and a gasket **60** is supported within the chamber **55** by supports **62**. The platform **58** has a hole **61** formed through the plate **59** and the gasket **60**. The core **41** is placed on the gasket **60** over the hole **61** and the shell **35** is positioned on the gasket around the rim **44** of the core. The chamber **55** is closed by a plate **70** having a center opening which is slightly larger than the outside diameter of the top portion of the shell **35**. An asbestos gasket **72** or the like which has an opening smaller than the inside diameter of the shell **35** but which is large enough to pour metal through is placed on the plate **70** so that it covers the top edge of the shell **35**.

When the mold and core have been positioned in the manner described, a vacuum is drawn within the chamber **55** around the shell **35**. At the same time, a vacuum is also produced within the core **41** because of the hole **61** which provides communication between the inside of the chamber **55** and the inside of the core. The resulting pressure differential on both the shell and the core serves to hold the members in their assembled position tight against the gasket **60**. This differential pressure is maintained during pouring of the mold to prevent relative movement of the core and shell.

The process of this invention will be largely apparent from the foregoing description. In summary, a set-up **10**, such as shown in FIG. 1, is formed and is provided with one or more laterally projecting divider portions **19**. The set-up may comprise a single cylindrical sprue member **11** which is provided with a ring divider between its ends. Alternatively, a plurality of sprue members **11** may be mounted in axial alignment on the rod **25** and the ends of the sprue members separated by plates such as shown at **27**. The plates provided between the ends of several sprue members function in the same manner as the divider ring **19**. A refractory mold wall is then formed around the set-up at each side of each divider portion. The divider portion circumferentially disrupts the mold wall so that when the sprue member or members are removed, the invested shell separates to provide separate refractory molds each having a through passage. Each refractory mold formed around the sprue member is then subjected to a pattern removal operation. When casting the shell molds, one end of each mold passage is closed and a core is preferably assembled within the mold passage in spaced relation to the inner mold wall surface to define a tubular sprue passage.

Many modifications and variations of the process of this invention will be apparent to those skilled in the art in the light of the foregoing detailed disclosure. Therefore, it is to 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. A process of investment molding comprising the steps of forming a set-up by locating divider means around the perimeter of a sprue means so that the divider means projects from the outer surface of the sprue means and is located between the ends of the sprue means, and attaching a plurality of laterally extending patterns to the sprue means on each side of the divider means, forming a refractory mold wall around the set-up at each side of the divider means, removing the set-up from within the mold wall to provide separate refractory molds each having a through passage and a plurality of pattern cavities gated into the passage, and closing one end of each mold passage so that molten metal can be cast into the molds.

2. A process according to claim **1**, wherein the refractory mold wall is formed by the steps of applying a refractory slurry coating to the set-up, stuccoing the slurry coating with refractory particles, and drying the stuccoed coating.

3. A process according to claim **2**, wherein the refractory slurry used to form the molds is removed from the peripheral surface of the divider means during application of the slurry to the set-up.

4. A process according to claim **1**, including the steps of assembling a core member within the passage of each mold to define sprue passageway means between the core member and the inner mold surface after the step of removing the set-up.

5. A process according to claim **1**, wherein the step of removing the set-up comprises first removing the sprue means and divider means, and thereafter placing the separate molds in a pattern removal medium and allowing the medium to circulate through the mold passages in order to destroy the patterns.

6. A process of ceramic shell molding comprising the steps of forming a set-up including a cylindrical sprue means, a divider portion which projects circumferentiatially from the sprue means between its ends and a plurality of laterally extending patterns attached to the sprue means, forming ceramic shell sections, around the set-up by applying refractory coatings to the set-up except for the outer peripheral surface of the divider portion, stuccoing the slurry coatings with refractory particles and drying the stuccoed coatings, removing the sprue means from within the shell sections to provide individual ceramic shell molds each having an open ended cylindrical passage therethrough, destroying the patterns by circulating a pattern removal medium through the mold passages to form mold cavities gated into the passages, closing one end of each mold passage and placing a core in each passage to define sprue passageway means between the core and the inner mold surface.

7. A process according to claim **6**, wherein said sprue means comprise a tube, a corrugated cardboard sleeve around the tube and a wax coating on the outside of the sleeve.

8. A process according to claim **7**, wherein the sprue means in a single cylinder formed by the tube and wax coated sleeve, and wherein the divider portion is formed by a ring around the outside of the wax coated sleeve.

9. A process of investment molding comprising the steps of:

(a) forming a set-up including sprue means in the form of a cylinder, a plurality of laterally extending patterns attached to the sprue means, and a divider portion which projects laterally from the sprue means between its ends, the divider portion being formed by providing a ring around the cylindrical sprue means,

(b) forming a refractory mold wall around the set-up at each side of the divider portion by applying a refractory slurry coating to the set-up, stuccoing the

slurry coating with refractory particles, and drying the stuccoed coating,

(c) removing the set-up from within the mold wall to provide separate refractory molds each having a through passage and a plurality of pattern cavities gated into the passage,

(d) and closing one end of each mold passage so that molten metal can be cast into the molds.

10. The process of investment casting comprising the steps of:

(a) forming a set-up including sprue means which comprises at least one cylinder including a tube, a sleeve around the tube and a wax coating on the outside of the sleeve, a plurality of laterally extending patterns attached to the sprue means, and a divider portion which projects laterally from the sprue means between its ends,

(b) forming a refractory mold wall around the set-up at each side of the divider portion by applying a refractory slurry coating to the set-up, stuccoing the slurry coating with refractory particles, and drying the stuccoed coating,

(c) removing the set-up from within the mold wall to provide separate refractory molds each having a through passage and a plurality of pattern cavities gated into the passage,

(d) and closing one end of each mold passage so that molten metal can be cast into molds.

11. A process of investment molding comprising the steps of forming a set-up by locating divider means around the circumference of a cylindrical sprue means so that the divider means projects from the outer surface of the sprue means between its ends, and attaching a plurality of laterally extending patterns to the sprue means at each side of the divider means, forming a continuous refractory mold wall around the set-up at each side of the divider means, removing the sprue means from within the having an open-ended cylindrical passage therethrough,

destroying the patterns by circulating a pattern removal medium through the mold passages to form pattern cavities gated into the cylindrical passages, closing one end of each mold passage and placing a core in each passage to define sprue pssageway means between the core and the inner mold surface.

12. A process of investment molding comprising the steps of:

(a) forming a set-up by locating divider means around the perimeter of a sprue means so that the divider means projects from the outer surface of the sprue means, and attaching a plurality of laterally extending patterns to the sprue means between both of its ends and the divider means,

(b) forming a continuous refractory mold wall around the set-up at each side of the divider means by the repeated steps of applying a stuccoed slurry coating to the set-up, removing the coating from the outer periphery of the divider means, and drying the coating, and

(c) removing the set-up from within the mold walls to provide separate refractory molds each having a through passage and a plurality of pattern cavities gated into the passage.

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164—28, 34, 129, 137, 350, 361

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,424,227 January 28, 1969

Claude H. Watts et al.

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 7, line 38, before "having" insert -- mold wall to provide individual refractory molds each --.

Signed and sealed this 24th day of March 1970.

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents