May 27, 1969 C. H. WATTS ET AL 3,446,266

INVESTMENT CASTING APPARATUS

Original Filed Dec. 28, 1962 Sheet 1 of 6

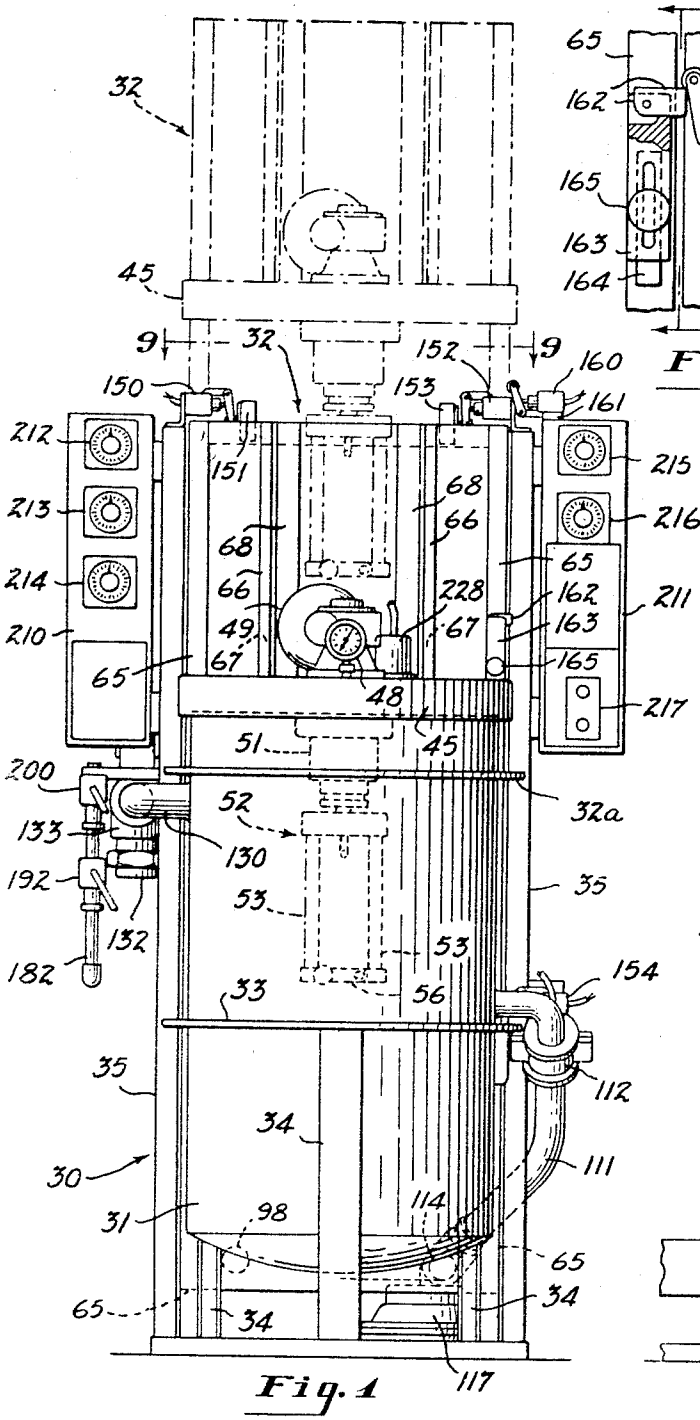


Fig. 1

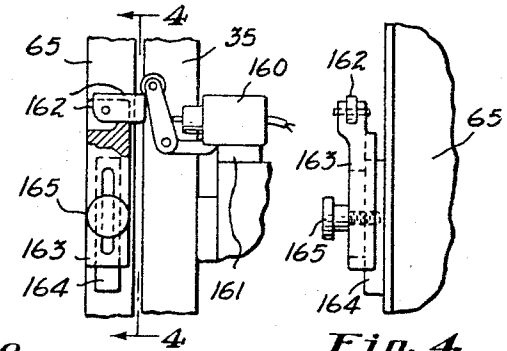


Fig. 3

Fig. 4

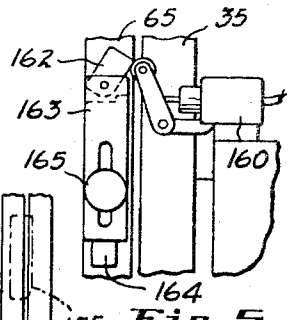


Fig. 5

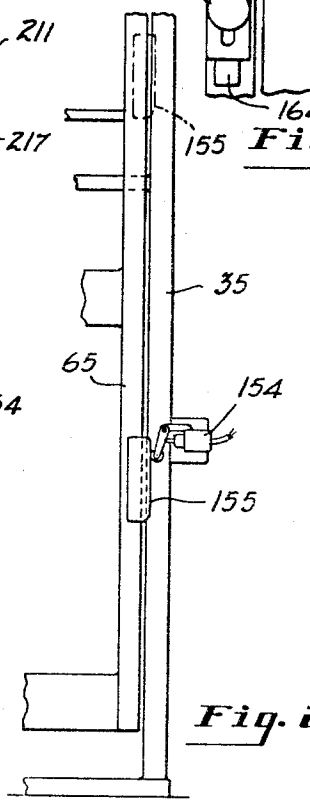


Fig. 2

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INVESTMENT CASTING APPARATUS

Original Filed Dec. 28, 1962 Sheet 2 of 6

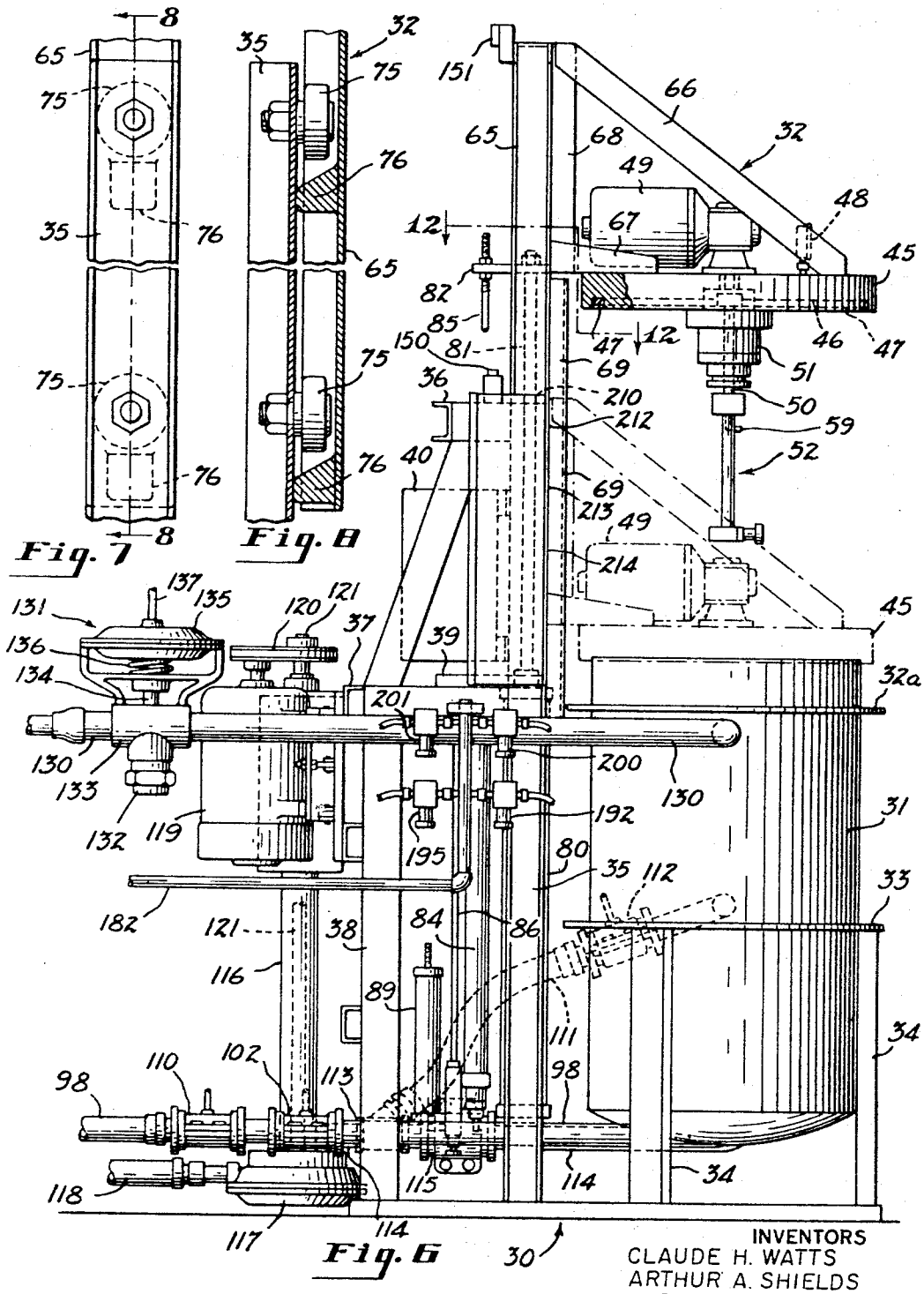


Fig. 7 Fig. 8

Fig. 6

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INVESTMENT CASTING APPARATUS

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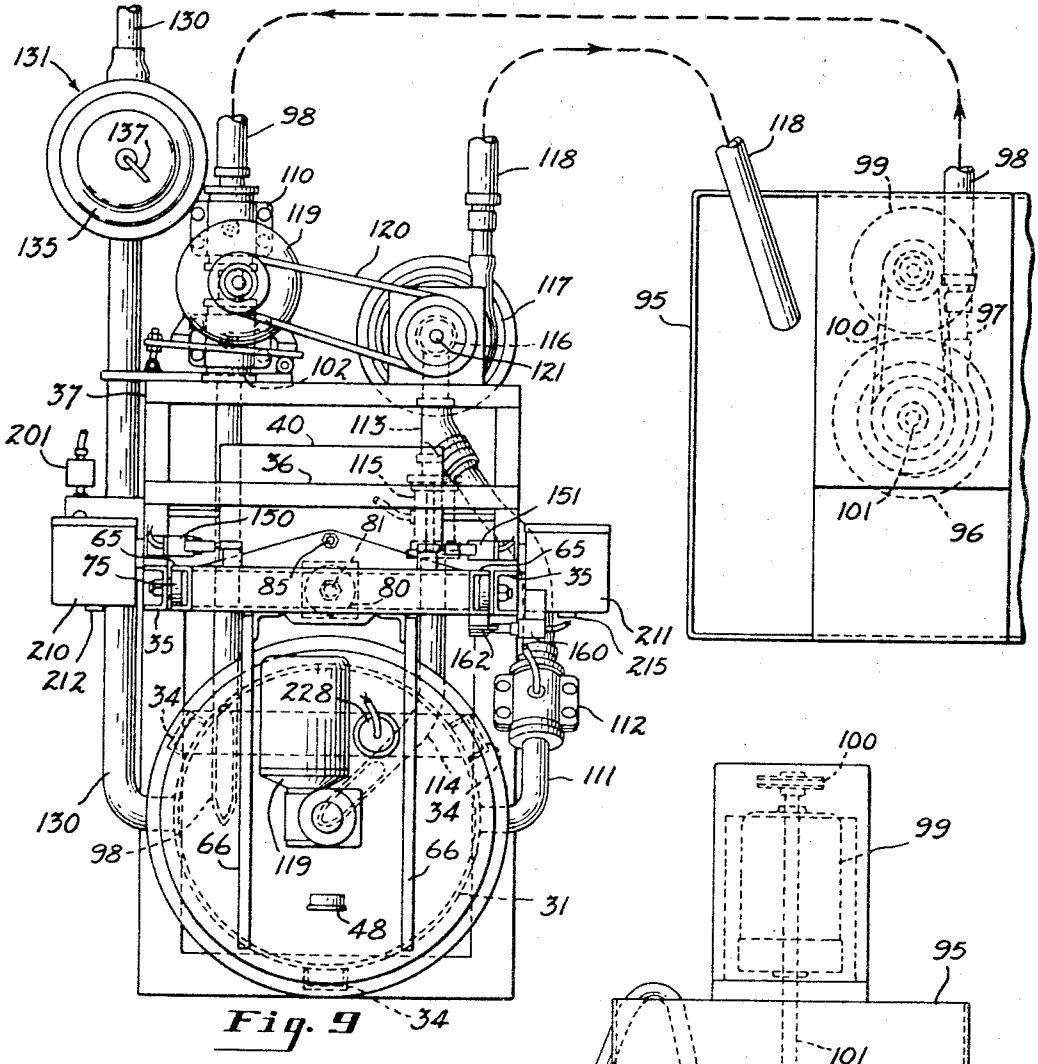


Fig. 9

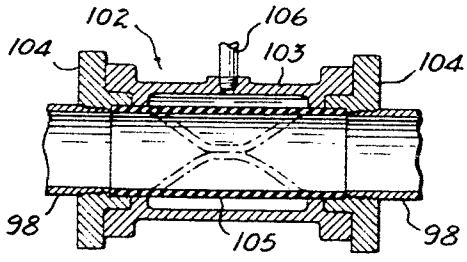


Fig. 11

Fig. 10

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INVESTMENT CASTING APPARATUS

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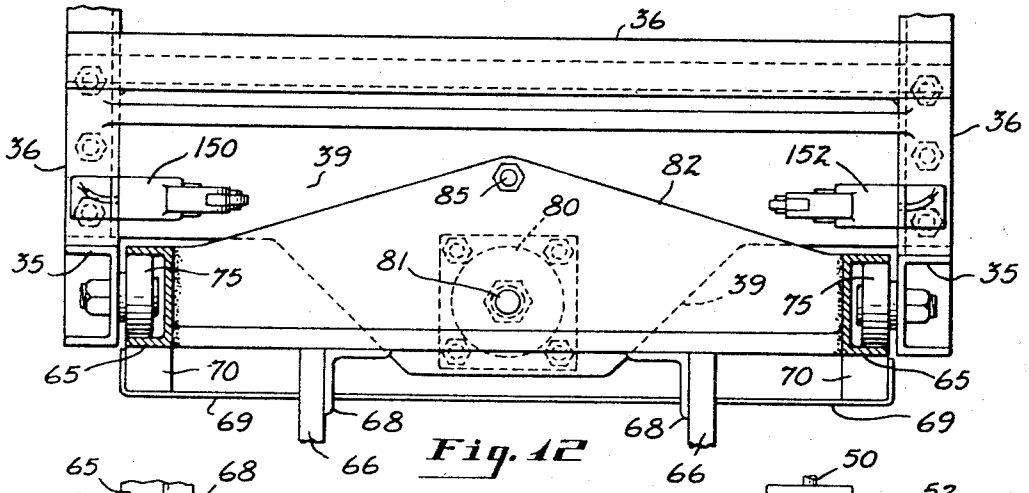


Fig. 12

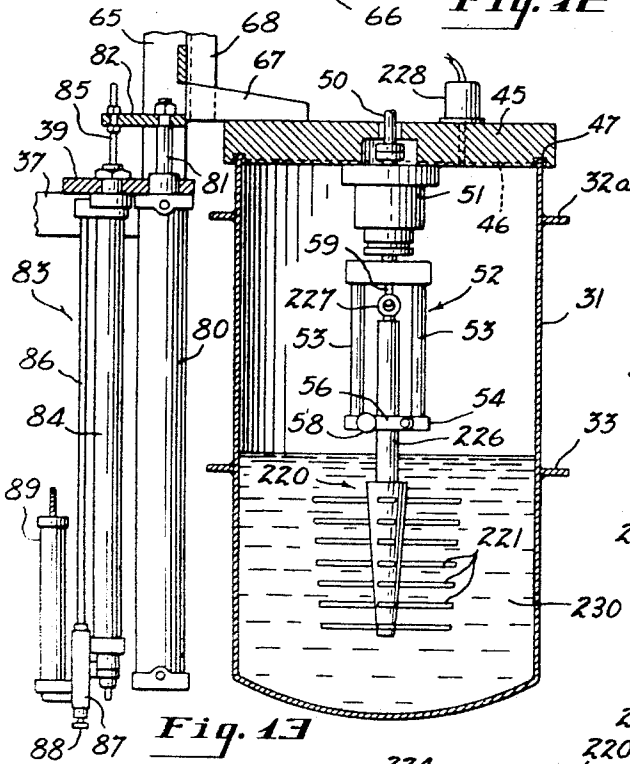


Fig. 13

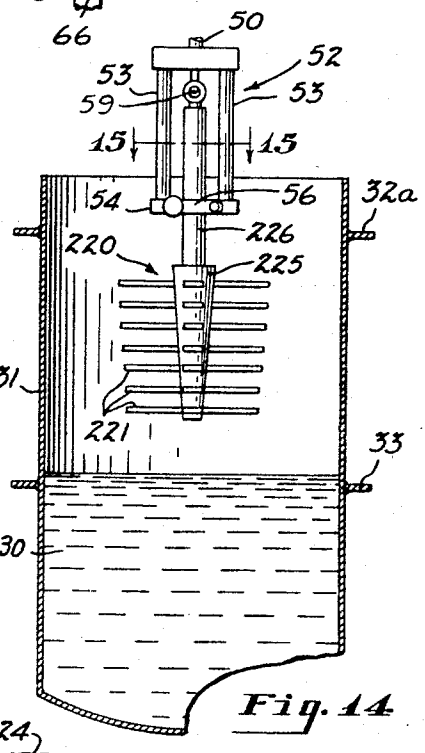


Fig. 14

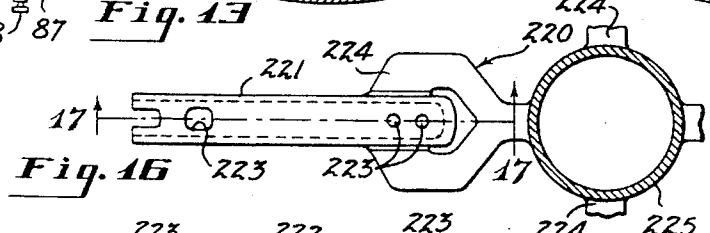


Fig. 16

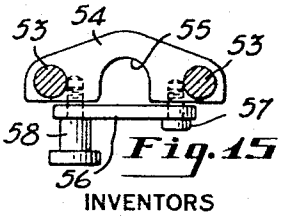


Fig. 15

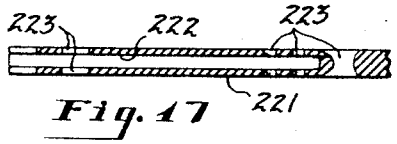


Fig. 17

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INVESTMENT CASTING APPARATUS

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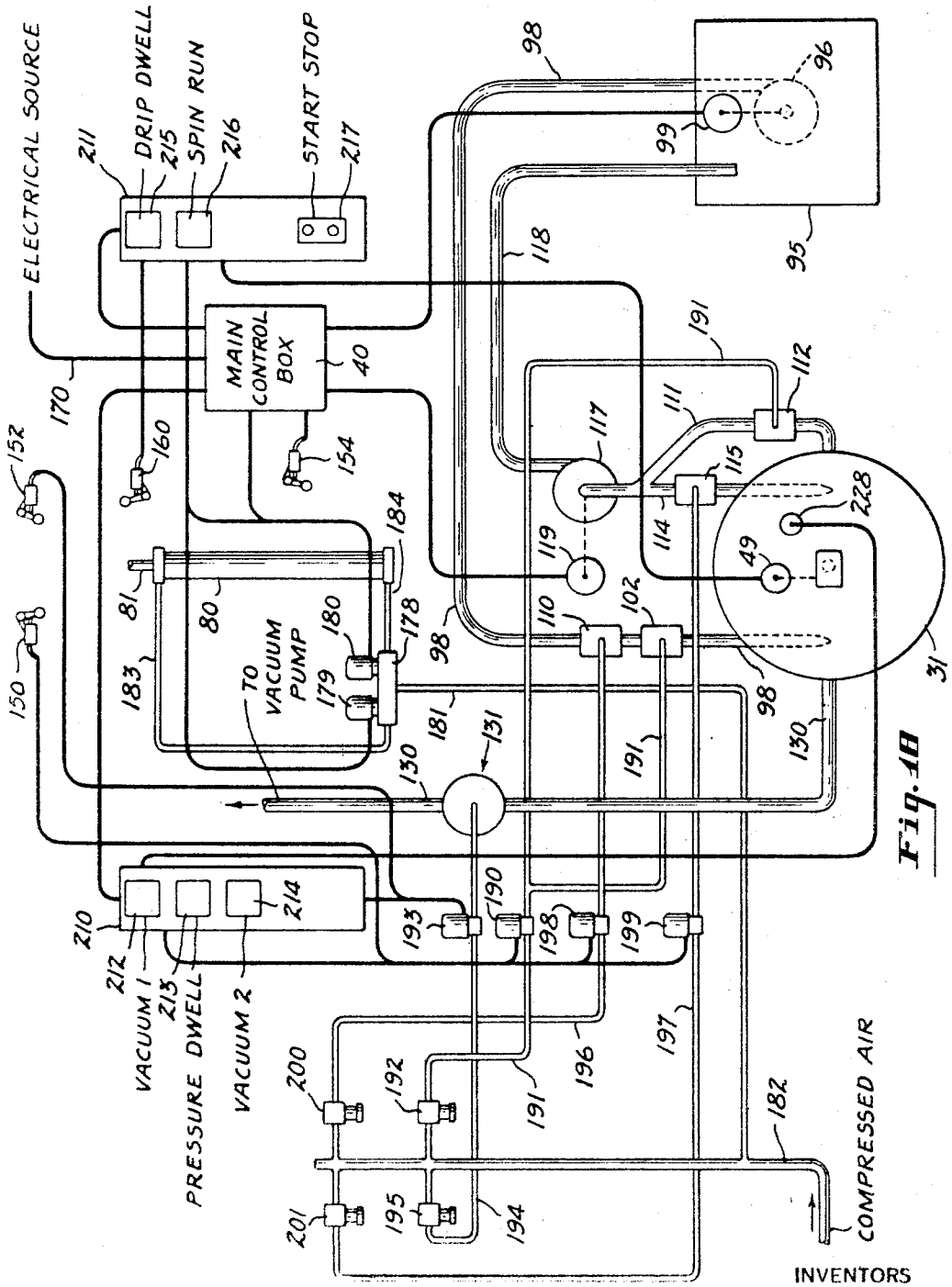


Fig. 4B

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INVESTMENT CASTING APPARATUS

Original Filed Dec. 28, 1962 Sheet 6 of 6

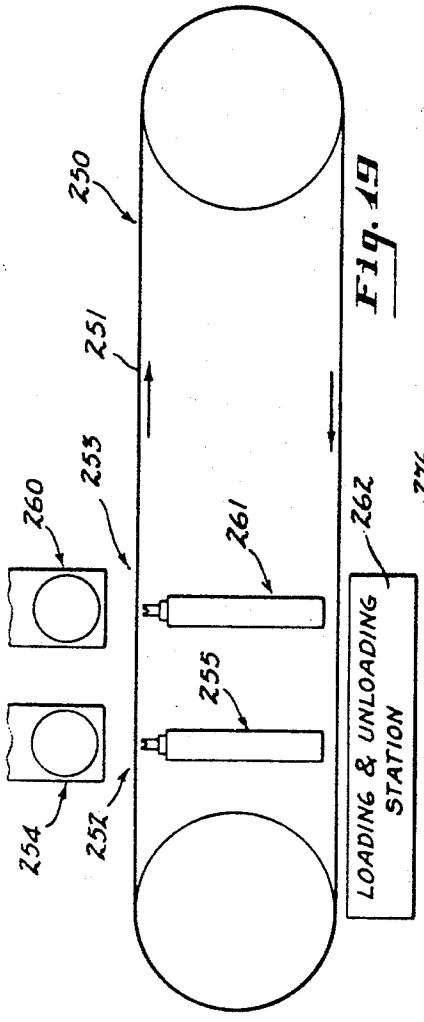


Fig. 19

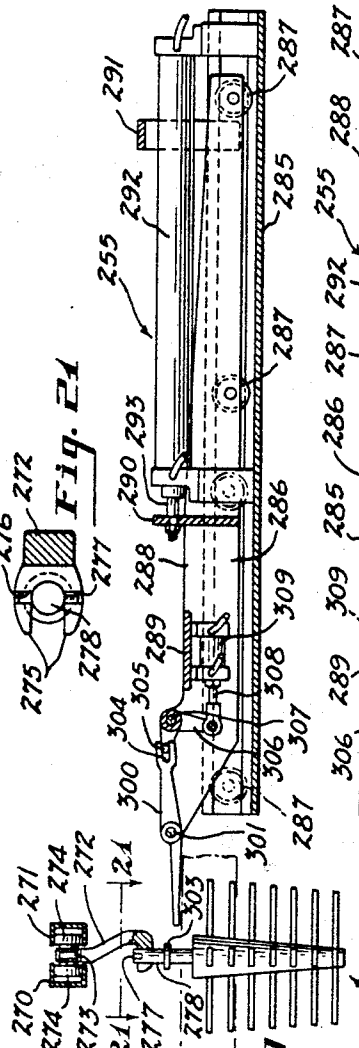


Fig. 21

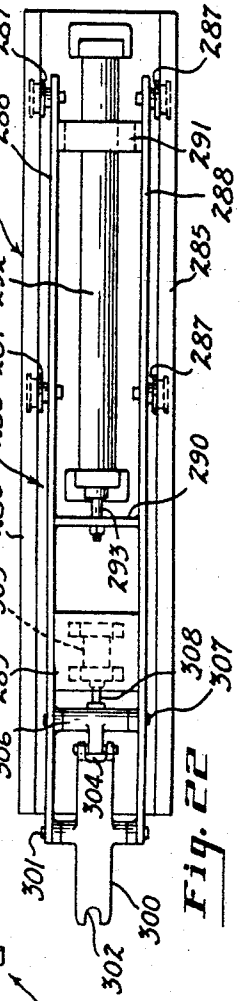


Fig. 22

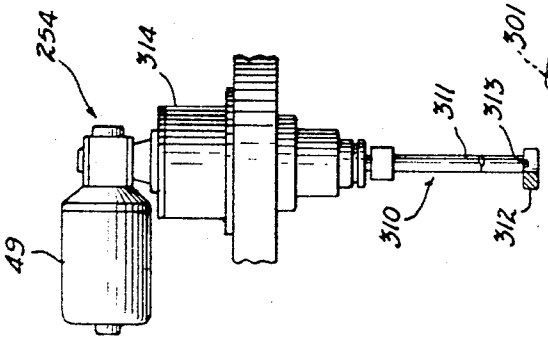


Fig. 20

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United States Patent Office 3,446,266
Patented May 27, 1969

3,446,266

INVESTMENT CASTING APPARATUS

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Original application Dec. 28, 1962, Ser. No. 248,076, now Patent No. 3,231,946, dated Feb. 1, 1966. Divided and this application Oct. 19, 1965, Ser. No. 509,464
Int. Cl. B22c 15/22
U.S. Cl. 164—160 5 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus for use in making refractory molds including a conveyor for transporting a pattern set-up from station to station, structure at one of the stations for applying a refractory slurry coating to a pattern set-up, the structure including means for rotatively supporting the set-up and for raising and lowering the set-up relative to a slurry tank, and means for transferring the set-up between the conveyor and the supporting means.

This application is a division of application Ser. No. 248,076 for Apparatus for Forming Ceramic Shell Molds, filed Dec. 28, 1962 and now Patent No. 3,231,946.

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.

As is known to those familiar with the art of investment casting, there is a growing trend in the industry to use ceramic shell molds in place of the conventional, bulk investment molds. This development of ceramic shell molding techniques has been prompted by the advantages which shell molds offer in many applications. For example, as compared with conventional investment molds, shell molds are lighter and easier to handle, exhibit increased permeability and thermal shock resistance, provide for easier knock-out and clean-up after casting, do not require flasks, and generally provide greater flexibility in processing.

In general, 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. These patterns are attached to a sprue form to constitute what is commonly known as a "set-up" or "tree." The formation of a shell mold around the assembly of patterns is accomplished by dipping the set-up into a refractory slurry of controlled viscosity followed by directional draining to attain uniform coverage. After draining excess slurry from the set-up, the slurry coating is then sanded or stuccoed with coarser refractory particles, as by dipping the set-up into an air-fluidized bed of suitable refractory material. The result is a coat of ceramic material having refractory particles embedded in the surface. This coat is hardened, usually by air drying at room conditions.

After the first coat is sufficiently hard and dry, the steps of dipping, 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 patterns. The usual shell thickness is from ⅛ inch to about ½ inch, although thicker or thinner shells may be formed for special situations. The disposable patterns are subsequently removed from the shell mold and the mold prepared for the casting operation.

A preferred refractory slurry used for dipping consists essentially of a suspension of a fine refractory powder in a

binder solution comprised mainly of colloidal silica sol and small amounts of an organic film-former, a wetting agent and a defoaming agent. The refractory powder usually is minus 100 mesh. Silicon dioxide, fused quartz, fused aluminum oxide, tabular aumina, and zircon (zirconium silicate) are the materials more commonly used.

The stuccoing material is generally of much larger particle size than the refractory powder used in the slurry. Suitable refractory materials employed for stuccoing include granular zircon, fused silica, silica, various aluminum silicate grogs including millite, sillimanite, fused alumina, tabular aluminum, and similar materials.

In order to obtain a satisfactory shell for casting, it is necessary to form a substantially uniform, dense, void-free coating around the pattern assembly. Heretofore, it has been difficult to obtain such a shell when producing relatively narrow cavities, it is difficult for the slurry to cover cored holes, slots, narrow passageways, and other openings. For example, in coating patterns which define relatively narrow cavities, it is difficult for the slurry to cover the innermost recesses of the cavities. If the viscosity of the slurry is reduced in an attempt to overcome this probcollect and cause voids which result in the cast piece being lem, the slurry usually is so thin that a discontinuous coating is formed on the pattern surface, resulting in rough surfaces and dirt inclusions in the finished casting. On the other hand, if the slurry is made thick enough to remain in the relatively small recesses, it is usually too thick satisfactorily to be forced into the recesses by conventional techniques. The problem of filling the pattern cavities is further complicated by the fact that each coat, after drying, tends to absorb moisture from the next dip, thereby casuing the slurry to thicken to a point that it cannot run completely into the cavities.

Furthermore, when one dip coating has dried, many small voids may be left by escaping moisture and gases. When the next coating is applied, it will displace the air trapped in these small voids or pockets and a bubbling effect will take place which may tend to weaken the shell and also to block the complete filling of the pattern cavities. It has also been found that this trapped air will often collect and cause voids which result in the cast piece being scrapped.

Prior to the inventions described and claimed in the above-identified U.S. Patent No. 3,231,946, it has been customary manually to handle the set-ups during the steps of dipping, draining, and stuccoing. Thus, when applying the slurry coatings, it has been necessary manually to turn the set-ups in various positions so that the slurry may flow into the pattern cavities. Similarly, in attempting to obtain uniform coverage, the set-ups must be carefully positioned subsequent to dipping in an effort to directionally drain excess slurry from the patterns. Because the set-ups have been handled manually, it has been difficult to obtain consistently satisfactory results. Furthermore, the handling of the set-ups is time-consuming and is not adapted to economical production operations.

The automatic apparatus of U.S. Patent No. 3,231,946 is particularly adapted to the production of ceramic shell molds and facilitates the application of dense, void-free slurry coating to pattern set-ups in a manner which obtains uniform coverage and reduces the problems of filling intricate pattern cavities, passages, openings and the like. In its preferred form, the apparatus operates automatically to place a pattern set-up in a tank containing a suitable refractory slurry. When the set-up has been placed in the slurry tank, the tank is closed and a vacuum is drawn, whereby dissolved and occluded air in the slurry is removed. The vacuum is continued for a predetermined period of time and air at atmospheric pressure is introduced into the tank so that the slurry is forced by air pressure

into all slots, cavities and other difficult-to-fill recesses of the patterns.

After the vacuum treatment, the pattern set-up is removed from the tank and directionally drained. In the preferred operation of the apparatus, this draining of the excess slurry is facilitated by rotating the set-ups. The set-up then may be stuccoed in the usual manner and the slurry coating allowed to harden. Each subsequent slurry coating may be applied in the same manner until a shell of the desired thickness has been built up.

The vacuum treatment of the slurry substantially prevents the detrimental occurrence of air bubbles on the surface of the patterns and thus assures that the slurry will uniformly coat and fill the intricate pattern details. A concomitant advantage is that dense refractory coatings are produced which are substantially free of voids that are conventionally formed by escaping gases. Consequently, when subsequent slurry coatings are applied, they will be free of air bubbles heretofore created by escaping air trapped in the voids of the previous coating. The apparatus thus makes it possible consistently to produce satisfactory shells using complex pattern shapes having intricate surface detail.

One important feature of the above-described apparatus is that it lends itself to automated production line procedures for dipping, draining and stuccoing the pattern assemblies. Accordingly, a purpose of this invention is to provide new and improved automated production line apparatus which embodies the constructions of Patent No. 3,231,946 and obtains all of the attendant advantages.

The apparatus contemplated by this invention preferably includes at least one dipping station and at least one stuccoing station. Dip-coating apparatus, which may be the same as that described above in connection with U.S. Patent No. 3,231,946, is disposed at the dipping station and a similar apparatus suitable for applying coarse refractory material to the coated set-ups is disposed at the stuccoing station. The various stations are connected by conveyor structure which includes hangers or the like suitable for transporting set-ups from station to station.

In operation the pattern set-ups are processed at a dip-coating station and are then connected to the conveyor structure for movement to a stuccoing station. Refractory material is applied to the coated set-ups at the stuccoing station and the set-ups are again transferred by the conveyor to a dip-coating station for application of the next slurry coating. Preferably, the length of the conveyor between one stuccoing station and the next dip-coating station is such that each stuccoed coating has sufficient time to dry and form a hard refractory layer. These operations of dipping, transferring to a stuccoing station, stuccoing and drying are repeated until shell molds of the desired thickness have been formed.

It will be apparent that the invention provides fully automatic apparatus suitable for forming ceramic shell molds in an economical manner. The formation of the molds is carried out in such a manner as to produce refractory coatings of consistently satisfactory quality and without the manual operations heretofore required.

Other advantages and a complete 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 front elevational view of a portion of the apparatus comprising the present invention;

FIGURE 2 is a fragmentary view of a portion of the apparatus shown in FIG. 1;

FIGURE 3 is a fragmentary view of another portion of the apparatus;

FIGURE 4 is a view taken on the line 4—4 of FIG. 3;

FIGURE 5 is a fragmentary view similar to FIG. 3, but showing the illustration portion of the apparatus in reverse operation;

FIGURE 6 is a side elevational view of a portion of the apparatus;

FIGURE 7 is a fragmentary view of a portion of the apparatus shown in FIG. 6;

FIGURE 8 is a cross-sectional view taken on the line 8—8 of FIG. 7;

FIGURE 9 is a top plan view taken ont he line 9—9 of FIG. 1 and shows a slurry reservoir tank which forms a part of the apparatus;

FIGURE 10 is an elevational view of the slurry reservoir tank;

FIGURE 11 is a cross-sectional view of a slurry shut-off valve;

FIGURE 12 is a view taken on the line 12—12 of FIG. 6;

FIGURE 13 is a fragmentary view illustrating part of the apparatus in an operative position in which a typical pattern set-up is immersed in a tank of suitable refractory slurry;

FIGURE 14 is a fragmentary view illustrating the pattern set-up when it has been partially withdrawn from the slurry tank for draining;

FIGURE 15 is a view taken on the line 15—15 of FIG. 14;

FIGURE 16 is a fragmentary view, partially in cross-section, of the typical pattern set-up shown in FIGS. 13 and 14;

FIGURE 17 is a cross-sectional view taken on the line 17—17 of FIG. 16;

FIGURE 18 is a view diagrammatically illustrating a preferred control system embodied in the apparatus of the invention;

FIGURE 19 is a diagrammatical plan view of the complete, automated production line apparatus comprising the present invention;

FIGURE 20 is a diagrammatic side elevational view, partially in cross section, of a portion of the apparatus illustrated in FIG. 19;

FIGURE 21 is a fragmentary, cross sectional view taken on the line 21—21 of FIG. 20; and

FIGURE 22 is a plan view of a portion of the apparatus shown in FIG. 20.

Referring now to the drawings, and to FIGS. 1, 6, 9 and 12 in particular, there is shown the preferred dip-coating mechanism which is located at the dip-coating stations of the apparatus of this invention. The illustrated construction of the mechanism comprises a framework **30** formed of suitable structural members. The framework **30** supports a slurry tank **31** and a vertically reciprocal carriage **32** above the tank. As will hereinafter be described in detail, the carriage **32** is operable to move a pattern set-up into the tank **31** which may be placed under vacuum, and subsequently to rotate the set-up after it has been partially withdrawn from the tank in order to facilitate proper draining.

In the illustrated construction, the slurry tank **31** is supported by a ring **33** which is welded to the outside of the tank wall. This ring is secured to the ends of upstanding frame members **34**. If desired, a stiffening ring **32***a* may be provided around the upper end portion of the tank.

The carriage supporting portion of the framework **30** is shown to include a pair of spaced, vertical channels **35**. The upper ends of these channel members **35** may be connected by an upper frame **36**. The channel members also are shown as being connected by an intermediate frame construction **37** which extends rearwardly from the channel members and is supported by members **38**. As shown most clearly in FIG. 12, the intermediate frame **37** includes a transversely extending cylinder support plate **39**. A main control box **40** is secured to the framework **30** above the cylinder support plate **39**.

The carriage structure **32** includes a cover **45** for the slurry tank **31**. As shown in FIG. 6. the lower surface of the cover **45** is provided with a groove **46** in which is seated an annular sealing ring **47**. In use, the cover **45** is engaged over the open upper end of the slurry tank **31** in sealed relationship therewith so that a vacuum can be drawn in the tank. Reference numeral **48** generally des-

ignates a vacuum gauge which may be mounted on the cover **45**.

A suitable motor **49** is provided on the cover **45** for rotating the pattern set-up after the vacuum treatment of the slurry in the tank **31**. The motor is drivingly connected to a vertical shaft **50** which extends through the cover and is journaled in the housing **51**. A pattern set-up clamp or fixture **52** is connected to the lower end of the shaft **50**. As shown most clearly in FIGS. 13–15, the fixture **52** includes a pair of depending bars **53** which support a bracket **54**. The bracket **54** includes a recess **55** adapted to receive a portion of the pattern set-up, and a clamping plate **56** is connected to the bracket in position to lock a portion of the pattern set-up in the recess **55**. In the illustrated embodiment, one end of the plate **56** is pivotally connected to the bracket by a member **57** (FIG. 15) and the other end of the bracket is provided with a threaded member **58** which is adapted to be engaged in a slot in the plate. The preferred construction of hte fixture **52** is also shown to include a hook **59** which is located above the bracket **54**.

Referring again to FIGS. 1, 6 and 12, the structure of the carriage **32** is shown further to include a pair of oppositely facing channels **65** which are suitably connected to form a rigid carriage frame assembly. The cover **45** is connected to an intermediate portion of this frame assembly by downwardly angled braces **66** which extend from the upper end of the frame and by rearwardly extending members **67**. These members **67** are secured to vertical bars **68** which also form a part of the carriage frame assembly. A cover plate **69** may be secured to the carriage channels **65** by means of spacer blocks **70** so as to extend across the carriage frame below the tank cover **45**.

The carriage **32** is supported for reciprocal movement on the frame **30** by vertically spaced rollers **75**. These rollers **75** are rotatably connected to the vertical frame channels **35** and are rollingly engaged within the carriage channels **65**. Referring particularly to FIGS. 7 and 8, it will be seen that lateral movement of the carriage **32** is prevented by vertically spaced shoes **76**. These shoes **76** are rigidly connected within the carriage channels **65** and slidably engage the surfaces of the frame channels **35**.

In the preferred construction of the invention, movement is imparted to the carriage **32** by an air cylinder **80**. The cylinder depends from the cylinder mounting plate **39** of the frame **30** and has its piston rod **81** secured to a carriage crosshead plate **82**. As shown most clearly in FIG. 12, the carriage crosshead plate **82** is secured between the carriage chanels **65**. In order to obtain smooth and accurate movement of the carriage **32**, a hydraulic control mechanism **83** (FIG. 13) also is preferably provided in conjunction with the main air cylinder **80**. This control mechanism is of conventional construction and includes a checking cylinder **84** which depends from the cylinder mounting plate and has its piston rod **85** connected to the carriage crosshead **82**. The piston (not shown) of the checking cylinder **84** includes a one-way valve which permits the hydraulic fluid to flow freely through the piston when it is forced to the bottom of the cylinder. A liquid transfer tube **86** is in open communication with the top of the checking cylinder **84** and communicates with the bottom of the cylinder through an adjustable needle valve assembly mounted in the housing **87**.

When the carriage assembly **32** is moved upwardly to pull the control piston rod **85** out of the checking cylinder **84**, liquid is forced from the top of the cylinder through the transfer tube **86** and the needle valve assembly into the bottom of the cylinder **84**. The rate of flow may be controlled accurate by the adjustment screw **88** which controls the size of the passage through the needle valve. The control mecahnism also is shown to include a spring-loaded reservoir cylinder **89** which receives the volume of liquid displaced from the cylinder **84** during downward movement of the piston rod **85**. This displaced liquid is returned to the main cylinder **84** on the upward piston stroke.

According to the preferred operation of the apparatus, the refractory slurry is circulated through the tank **31** except during those intervals when the tank has been closed and a vacuum drawn. To this end, there is preferably provided a slurry reservoir **95**. As shown most clearly in FIGS. 9 and 10, a rotary slurry pump **96** is mounted on the bottom of the reservoir **95** and a conduit **98** is connected between the outlet **97** of the pump and the bottom of the tank **31**. The pump **96** is actuated to pump the slurry from the reservoir **95** into the tank **31** by a motor **99** which is mounted on top of the reservoir. As shown, the motor **99** is drivingly connected by a belt **100** to a vertical pump shaft **101** which extends downwardly through the reservoir.

A slurry valve **102** is provided in the conduit **98** for shutting off the supply of refractory slurry prior to producing a vacuum in the slurry tank. This slurry valve **102** may be of conventional construction and is shown in FIG. 11 to include a casing **103** and end plates **104** which are adapted to receive the connecting portions of the conduit **98**. A flexible sleeve **105** of abrasion-resistant material is mounted within the casing **103**. By introducing air under pressure into the casing through the pipe **106**, the flexible sleeve **105** may be constricted, as illustrated in FIG. 11 by broken lines, thereby shutting off the flow of slurry through the valve. It will be apparent to those skilled in the art that other suitable valve constructions which are resistant to the abrasive slurry may be used.

A throttle valve **110** is preferably provided in the conduit **98** upstream from the slurry shut-off valve **102** for the purpose of controlling the rate of slurry flow from the reservoir into the slurry tank **31**. The valve **110** may be identical in construction to the valve **102** and operated by creating sufficient pressure in the valve casing to distort the flexible sleeve to partially restrict the slurry flow. Thus, by controlling the air pressure within the casing, the size of the flow passage defined by the flexible sleeve can be accurately determined.

An overflow conduit **111** is connected to the side of the tank **31** in order to maintain a substantially constant depth of slurry in the tank. A slurry shut-off valve **112** is preferably provided in the conduit **111** in order to prevent slurry from being drawn into the tank when a vacuum is produced. The overflow conduit **111** is connected by a suitable fitting **113** to an exhaust conduit **114** which leads from the bottom of the tank **31**. The exhaust conduit **114** also is provided with a slurry cut-off valve **115** which is normally maintained closed and is opened only to drain the slurry tank.

The overflow conduit **111** and the exhaust conduit **114** are jointly connected by the fitting **113** to a standpipe **116** which is in turn connected to the inlet of a rotary slurry pump **117**. This slurry pump **117** serves to pump the slurry through a conduit **118** back into the reservoir **95**. As shown in FIGS. 6 and 9, the pump **117** is driven by a motor **119** which is connected to the frame portion **37**. The motor **119** is drivingly connected by a belt **120** to the vertical pump shaft **121** which extends downwardly through the standpipe **116**.

A vacuum line **130** also is connected into the side of the slurry tank **31** at a point which is spaced above the opening of the overflow conduit **111** and to a suitable vacuum pump (not shown). Referring specifically to FIG. 6, it will be seen that a spring-loaded valve **131** is provided in the vacuum line **130** for the purpose of opening the line to atmospheric pressure and thereby breaking the vacuum in the slurry tank **31**. The illustrated construction of the vacuum valve **131** includes a normally open air inlet **132** which can be closed by a suitable valve (not shown) within the housing **133**. The stem **134** of the valve extends through the valve housing **133** into operative connection with a flexible diaphragm (not shown) which is secured within a diaphragm housing **135**. A spring **136** serves to bias the valve to its normally open position and an air inlet pipe **137** is connected to the housing **135** for introducing air under pressure above the diaphragm. As air is introduced into the diaphragm housing **135**, the dia-

phragm is forced downwardly to seat the valve against the action of the spring **136** and thereby close the air inlet **132**. When the supply of air to the diaphragm housing **135** is shut off, the action of the spring **136** opens the valve so that air at atmospheric pressure is admitted through the air inlet **132** and the conduit **130** to the tank **31**.

Suitable limit switches are provided for controlling the various operations of the apparatus in a manner which will hereinafter be described in detail. As shown in FIG. 1, a limit switch **150** is mounted on one of the vertical channel members **35** of the frame **30**. This limit switch acts to close the slurry valves **102** and **112** when the carriage **32** has been moved to its down position and the slurry tank has been closed by the cover **45**. According to the illustrated arrangement, the limit switch **150** is actuated by a control block **151** which is connected to the top of the carriage. Another limit switch **152** is mounted on the other frame channel **35** and serves to actuate the vacuum valve **131** when the carriage is in its down position. This limit switch is also actuated by a suitable block **153** connected to the top of the carriage.

A limit switch **154** is provided for shutting off the slurry pumps **96** and **117** when the slurry tank **131** has been closed. As shown in FIG. 2, this limit switch **154** is mounted on one of the frame channels **35**. An actuating shoe **155** is connected to the adjacent carriage channel **65** in position to actuate the switch and stop the slurry pumps when the carriage is in the illustrated down position. After the pattern assembly has been dipped in the slurry and the carriage is moved upwardly to open the slurry tank, the shoe **155** passes out of contact with the switch **154** so that the pumps are again actuated to circulate the slurry through the tank.

The operation of the spin motor **49** is controlled by a limit switch **160** which is connected to the top of the frame **30** by a bracket **161**. Referring specifically to FIGS. 3, 4 and 5, it will be seen that the switch **160** is adapted to be actuated during upward movement of the carriage **32** by a shoe **162** which is pivotally connected within a bifurcated upper end of a channel member **163**. The channel member **163** is vertically adjustable on a guide **164** which is secured to the carriage channel **65**, and a clamping screw **165** is provided for holding the channel member **163** in its adjusted position. When the carriage **32** is moved upwardly, the shoe **162** will contact the switch **160**, as shown in FIG. 3, to initiate actuation of the motor **49**. During downward travel of the carriage, the shoe will pivot out of contact with the limit switch, as shown in FIG. 5.

Reference is now made to FIG. 18 which diagrammatically illustrates a preferred control system for the apparatus, including the fluid ducts and suitable electric conduits which are represented by heavy lines. The electrical conduits will be understood to contain one or more circuits which are electrically connected to the various valves, switches, and control boxes in a manner which will be readily apparent to those skilled in the art in view of the following description.

As shown in FIG. 18, a two-way fluid valve **178**, which is controlled by solenoid operated pilot valves **179** and **180**, is provided for admitting air to the main cylinder **80**. Air under pressure is supplied to the valve **178** through a branch conduit **181** which connects to a main inlet air line **182**. The valve **178** is connected to the top of the main cylinder **80** through a fluid conduit **183** and to the bottom of the cylinder by a fluid conduit **184**. When the apparatus is actuated to initiate a dipping operation, the pilot valve **179** is operated to shift the valve **178** and admit air to the top of the main cylinder **80**, thereby causing downward movement of the carriage **32**. At the end of the dipping operation, the valve **178** is actuated by the pilot valve **180** to admit air into the bottom of the main cylinder and affect reverse movement of the carriage.

As generally described above, the limit switches **150**, **152**, **154** are actuated by the carriage when it has been moved to close the slurry tank **31**. The limit switch **150** is in operative circuit relation with a solenoid-operated valve **190** which is disposed in a fluid conduit **191**. The conduit **191** is connected between the main inlet air line **182** and each of the slurry valves **102** and **112**. When the limit switch **150** is actuated, the valve **190** is opened to admit air to the slurry valves **102** and **112** and thereby close the slurry conduits **98** and **111**. Preferably, the fluid conduit **191** is provided with a pressure regulator **192** in order to control the air pressure in the slurry valves.

The limit switch **152** is electrically connected to a normally closed, solenoid operated valve **193** which is in a fluid conduit **194**. The fluid conduit **194** is connected between the main inlet air line **182** and the diaphragm housing of the vacuum valve **131**. As shown, a pressure regulator valve **195** also may be disposed in the conduit **194**. When the limit switch **152** is actuated by the carriage **32**, the valve **193** is opened to admit air under pressure into the diaphragm housing of the vacuum valve **131**. As explained above, the air under pressure which is admitted to the vacuum valve causes the air inlet of the valve to be closed so that a vacuum can be produced in a slurry tank by a suitable vacuum pump (not shown). The limit switch **154** is connected through the main control box **40** to the slurry pump motors **99** and **119** so that the slurry pumps will be shut off at approximately the same time the slurry valves are closed and the valve **131** is actuated to affect a vacuum in the slurry tank **31**.

The throttle valve **110** and the slurry valve **115** in the drain conduit **114** for the slurry tank are respectively connected to the main air line **182** by branch lines **196** and **197**. Solenoid operated valves are in circuit relation with the main control box **40**. As generally described above, the valve **198** is normally open during operation of the apparatus so that throttle valve **110** may regulate the flow of slurry into the tank **31** when the shut-off valve **102** is open. A pressure regulator **200** also is provided in the air line **196** in order to obtain the desired pressure in the throttle valve **110**. The solenoid valve **199** is normally open and is closed only when it is desired to drain the slurry tank. As shown, the pressure in the air line **197** is controlled by another pressure regulator **201**.

The preferred control system is further shown to include a pair of timer boxes **210** and **211** which may be connected to the frame members **35**. Connected within the timer box **210** are a first vacuum timer **212**, a pressure dwell timer **213**, and a second vacuum timer **214**. The timer box **211** includes a drip dwell timer **215**, a spin timer **216** and a start-stop switch **217**. As will be made more apparent, the various timers are disposed in circuit relation with the limit switches and solenoid valves to provide an automatic cycle of operations wherein the vacuum timer **212** controls the time of a first vacuum treatment of the slurry. The pressure dwell timer **213** and the second vacuum timer **214** act in conjunction to provide for an optional, second vacuum treatment before the pattern assembly is removed from the slurry. When the pattern assembly has been removed from the slurry after dipping, the timer **215** is activated to allow the assembly to directionally drain for a predetermined time, and then the timer **216** is actuated to operate the spin motor **49**.

Before describing the operation of the dip-coating apparatus in detail, reference is made to FIGS. 13, 14, 16 and 17 which, as previously noted, illustrate a typical pattern set-up **220** suitable for use in forming a ceramic shell mold. As shown, the set-up **220** consists of a plurality of expandible patterns **221**, each of which includes a longitudinal slot **222** and transverse openings **223**. The gating **224** of the patterns is attached to a center sprue form **225** which also may be formed of an expendible material. Those familiar with the art of lost pattern precision casting, and particularly with shell molding techniques, will understand that, in forming a ceramic shell mold around the illustrated set-up, it is necessary to completely fill the narrow slots **222** and to core the openings **223** so that,

when the patterns are subsequently removed from the mold, pattern cavities are formed which define the exact shapes of the desired castings.

In accomplishing the foregoing by means of the above-described apparatus, the pattern set-up **220** is connected to the fixture **52** by a rod **226** which has one end suitably attached to the sprue form **225** and an opposite end which preferably is provided with a hook **227**. As shown, an intermediate portion of the rod **226** is secured in the bracket recess **55** by the clamping plate **56**, while the hook **227** is connected to the fixture hook **59**. With the pattern set-up secured to the fixture **52**, the start-stop switch **217** is closed to activate the pilot valve **179** of the valve **178** so that the carriage **32** is moved from the solid line position illustrated in FIG. 6 to the down position shown in FIGS. 1 and 13. When the carriage **32** has been moved to the down position to close the tank **31** and immerse the setup **220** in the slurry **230** (FIG. 13), the limit switches **150** and **152** are contacted to initiate the vacuum in the tank **31** and to close the slurry valves **102** and **112**. At substantially the same time, the limit switch **154** is contacted to stop the slurry pump motors **99** and **119**.

A vacuum switch **228** is mounted on the cover **49** and is in circuit relation with the vacuum timer **212**. After the desired vacuum has been produced in the tank **31**, the vacuum switch **228** is activated to start the timer **212**. This timer is preset to hold the vacuum for a period calculated to clear air bubbles from the slurry around the patterns. At the end of the vacuum period, the solenoid valve **193** is closed to admit ambient air through the vacuum valve **131** into the slurry tank. In this manner, the slurry is forced by air pressure into all undercuts, internal slots, holes and other difficult to fill recesses of the patterns.

In the next operation, either the pilot valve **180** may be activated to start return movement of the carriage **32** or a second vacuum treatment is initiated. In the latter instance, the pressure dwell timer **213** is automatically started and this timer serves to hold the vacuum valve **131** open for a sufficient time to assure that the pressure in the slurry tank is at atmospheric pressure. Thereafter, the vacuum valve is closed and the timer **214** is started to affect the second vacuum treatment. At the end of this optional vacuum treatment, the pilot valve **180** is activated to start the carriage **32**.

The carriage **32** is moved upwardly by the main cylinder **80** to the position shown in FIG. 14 wherein the set-up **220** is removed from the slurry and is in the upper portion of the slurry tank. Thereupon the limit switch **160** is contacted to close the main cylinder valve **178** and to start the drip dwell timer **211**. The timer **211** is set to allow sufficient time for directional draining of excess slurry from the setup. In this way, substantially uniform external coverage of the patterns is obtained without disturbing the ceramic slurry forming the internal cores.

At the end of the drip dwell period, the spin motor **49** and the spin timer **216** are actuated. The set-up **220** is rotated by the motor **49** a sufficient length of time, as determined by the setting of the timer **216**, to affect draining of excess slurry from the pattern cavities and recesses. The cycle of operations is then completed by actuation of the pilot valve **180** which causes the main cylinder **80** to return the carriage **32** to its up position.

Subsequent to the above-described operations, stuccoing material is applied to the slurry coating, as by immersing the setup in an air-fluidized refractory bed, and the coating allowed to harden. Additional coatings may be applied in the same manner, stuccoed and allowed to harden until a ceramic shell of the desired thickness has been produced. It will be understood that lhe vacuum treatment of the slurry may be affected during each dip coating step in building up the shell or, depending upon the pattern configuration and the viscosity of the slurry, during only selected applications of the slurry to the patterns.

In accordance with the present invention, the above-described dip-coating apparatus is embodied in an automatic production line mechanism suitable for completely forming ceramic shell molds. As diagrammatically illustrated in FIG. 19, the mechanism **250** of the invention generally comprises a suitable conveyor **251** adapted to carry a plurality of pattern set-ups. The conveyor is actuated by a suitable drive mechanism (not shown) to move the several pattern set-ups in step-wise fashion between work stations **252** and **253**.

The first work station **252** constitutes a dipping position at which each set-up is immersed in refractory slurry. The apparatus for dipping the set-ups is generally indicated by reference numeral **254** and may be substantially the same as that described in conjunction with FIGS. 1–18. As shown, a loading mechanism **255** is provided for transferring each set-up to the dipping apparatus **254** and then returning the set-ups to the conveyor **251** after the dipping operation has been completed.

From the dipping station **252**, the slurry coated set-ups are moved to the work station **253** at which the set-ups are stuccoed with a suitable refractory material. In accordance with conventional shell forming techniques, this stuccoing operation may be carried out by immersing the set-ups in a container of the stuccoing material which is continuously agitated by a stream of air to provide a fluid-like bed. The apparatus for handling the set-ups is generally indicated at **260** and may be comprised simply of a vertically reciprocal carriage similar to the previously described carriage **32** which is mounted on a guide frame and which is provided with a fixture, as will hereinafter be described, for holding the set-ups. A loading mechanism **261**, which is similar to the mechanism **255**, is provided for transferring the set-ups between the conveyor and the holding fixture of the stuccoing apparatus **260**.

The conveyor **251** is of sufficient length to allow the slurry coatings on the patterns to harden after being moved from the stuccoing station **253** and before being returned to the station **252** or transferred to another dipping station for the next application of slurry. If desired, this hardening of the slurry may be facilitated by forced air drying. When the shells have been built up to the desired thickness by repeated dipping, stuccoing and drying of the set-ups, the molds may be removed from the conveyor at a loading and unloading station **262** and new set-ups connected to the conveyor.

Reference is now made to FIGS. 20, 21 and 22 which illustrate the apparatus **250** in more detail. According to this embodiment, the conveyor **251** is a typical trolley-type conveyor and comprises spaced rails **270** and **271** along which are mounted traveling hooks **272** (only one of which is shown). These hooks are connected in spaced relationship by a conveyor chain **273** and are provided with rollers **274** which rollingly engage the rails **270**, **271**. As shown most clearly in FIG. 21, each hook **272** preferably has a bifurcated end **275** which includes a transverse slot **276**. This slot **276** is adapted to receive a crosspin **277** which is connected to the end of the rod **278** of each set-up **279**. In this manner, the set-ups can be easily connected to the hooks **272** for movement by the conveyor.

The loading mechanism **255** which is associated with the dipping apparatus **254** includes a stationary frame channel **285** supported by suitable structural members (not shown). A carriage **286** is mounted for movement along the frame channel **285** by rollers **287**. As shown, the carriage **286** is formed by side plates **288** which are transversely connected by plates **289**, **290** and **291**. Movement is imparted to the carriage **286** by a fluid cylinder mechanism **292** which is secured to the fixed channel **285**. The piston rod **293** of the cylinder mechanism **292** is connected to the transverse plate **290** of the carriage.

At the front end of the carriage **286**, there is provided a transfer mechanism for engaging the pattern set-ups. This transfer mechanism is shown to comprise a lever

arm 300 which is journaled intermediate its ends on a pivot shaft 201 mounted between the carriage side plates 288. The forward end of the lever arm 300 has a recess 302 which is adapted to receive the rod 278 of each set-up 279 so that the arm may liftingly engage a collar 303 on the rod.

The opposite end of the lever arm 300 is bifurcated and a transverse slot 304 is formed in each leg. These slots 304 are adapted to receive oppositely extending lugs 305 on one arm of a bell crank 306. The bell crank 306 is fulcrumed on a shaft 307 connected between the carriage side plates 288, and its other arm is pivotally connected to the piston rod 308 of a fluid cylinder mechanism 309. As shown, the fluid cylinder mechanism 309 is secured to the underside of the carriage plate 289 so that operation of the cylinder mechanism serves to pivot the lever arm 300 on the horizontal shaft 307.

In operation, the conveyor 251 is actuated to position a set-up 279 adjacent the dipping apparatus 254. Thereupon the fluid cylinder mechanism 292 of the loading mechanism is actuated to move the carriage 286 to the left (as viewed in FIG. 20) until the rod 278 is engaged in the recess 302 of the lever arm 300. The movement of the carriage is momentarily stopped in this position and the fluid cylinder mechanism 309 is retracted so that the lever arm 300 is caused to pivot and lift the cross-pin 277 of the rod 278 from engagement with the hook 272. Movement of the carriage 286 may then be continued to transfer the set-up 279 adjacent the fixture 310 of the apparatus 254.

The fixture 310 differs from the fixture 52 and comprises a shaft 311 having a head 312 which is formed with a slot 313 for receiving the cross-pin 277. The shaft 311 is operatively connected to the spin motor 49 by a magnetic one-point clutch 314. This clutch operates to return the shaft 311 to the same position after each spin cycle so that the head 312 is in position to receive the cross-pin 277. As noted above, the fixture of the stuccoing apparatus 260 preferably corresponds to the fixture 310.

When the set-up 279 has been positioned adjacent the fixture 310, the fluid cylinder mechanism is extended to lower the set-up until the cross-pin 277 is seated in the slot 313. Thereupon the carriage 286 is withdrawn and the apparatus 254 is operated in the manner described in conjunction with the preferred embodiment of the invention to slurry coat the set-up 279.

At the end of the dipping operation, the carriage 286 again is extended and the cylinder mechanism 309 operated to pivot the arm 300 in lifting engagement with the set-up. By returning the carriage and reversing the movement of the cylinder mechanism 309, the set-up can be replaced on the conveyor hook 272 for movement to the stuccoing station 253. It will be understood that the loading mechanism 261 at the stuccoing station is operable in the same manner as the mechanism 255 to engage the coated set-up on the fixture of the stuccoing apparatus 260 and then return the set-up to the conveyor for the drying cycle.

Many modifications and variations of the invention will be apparent to those skilled in the art in view of the foregoing detailed description. Therefore, it is to be understood that, within the scope of the appended claims, the invention can be practiced otherwise than as specifically disclosed.

What is claimed is:

1. An apparatus for forming ceramic shell molds by dip-coating a pattern set-up in a refractory slurry, stuccoing the pattern set-up with refractory material, and drying the slurry coating, said apparatus comprising conveyor means, said conveyor means including means for supporting a pattern set-up, a dip-coating mechanism mounted adjacent said conveyor means for immersing the set-up in refractory slurry, first loading means associated with said conveyor means for transferring the set-up to said dip-coating mechanism and then returning the set-up in operative connection with said conveyor means, a stuccoing mechanism mounted adjacent said conveyor means for applying refractory material to the slurry coated set-up, and second loading means associated with said conveyor means for transferring the set-up to said stuccoing mechanism and then returning the set-up into operative connection with said conveyor means.

2. The apparatus as claimed in claim 1 wherein said dip-coating mechanism and said stuccoing mechanism are each comprised of a vertically reciprocal carriage and a fixture connected to said carriage for holding the set-up.

3. Apparatus for use in making refractory molds comprising conveyor means for transporting a pattern set-up, said conveyor means including means for suspending a pattern set-up; structure adjacent said conveyor means for applying a refractory slurry coating to a pattern set-up, said structure including a tank for refractory slurry, means adjacent said tank for supporting a pattern set-up for rotation, said supporting means being movable relative to said tank for lowering a pattern set-up into the slurry in said tank and raising the set-up from the slurry, a cover adapted to be placed in air-tight sealed engagement with said tank when said supporting means is lowered, and means connected to said tank for producing a vacuum therein when said cover is in sealed engagement with said tank; and means operable between said conveyor means and said structure for transferring a pattern set-up between said supporting means of said structure and said conveyor means.

4. Apparatus as claimed in claim 3 wherein said cover is movable with said supporting means.

5. Apparatus as claimed in claim 3 including a second structure adjacent said conveyor means and spaced from said first-mentioned structure, said second structure including means for supporting a pattern set-up, said means being movable to lower the pattern set-up into a fluidized bed of refractory material and to raise the set-up from the bed; and means operable between said conveyor means and said second structure for transferring a set-up between said conveyor means and said supporting means of said second structure.

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