CASTING APPARATUS FOR ENCAPSULATING ELECTRICAL CONDUCTORS

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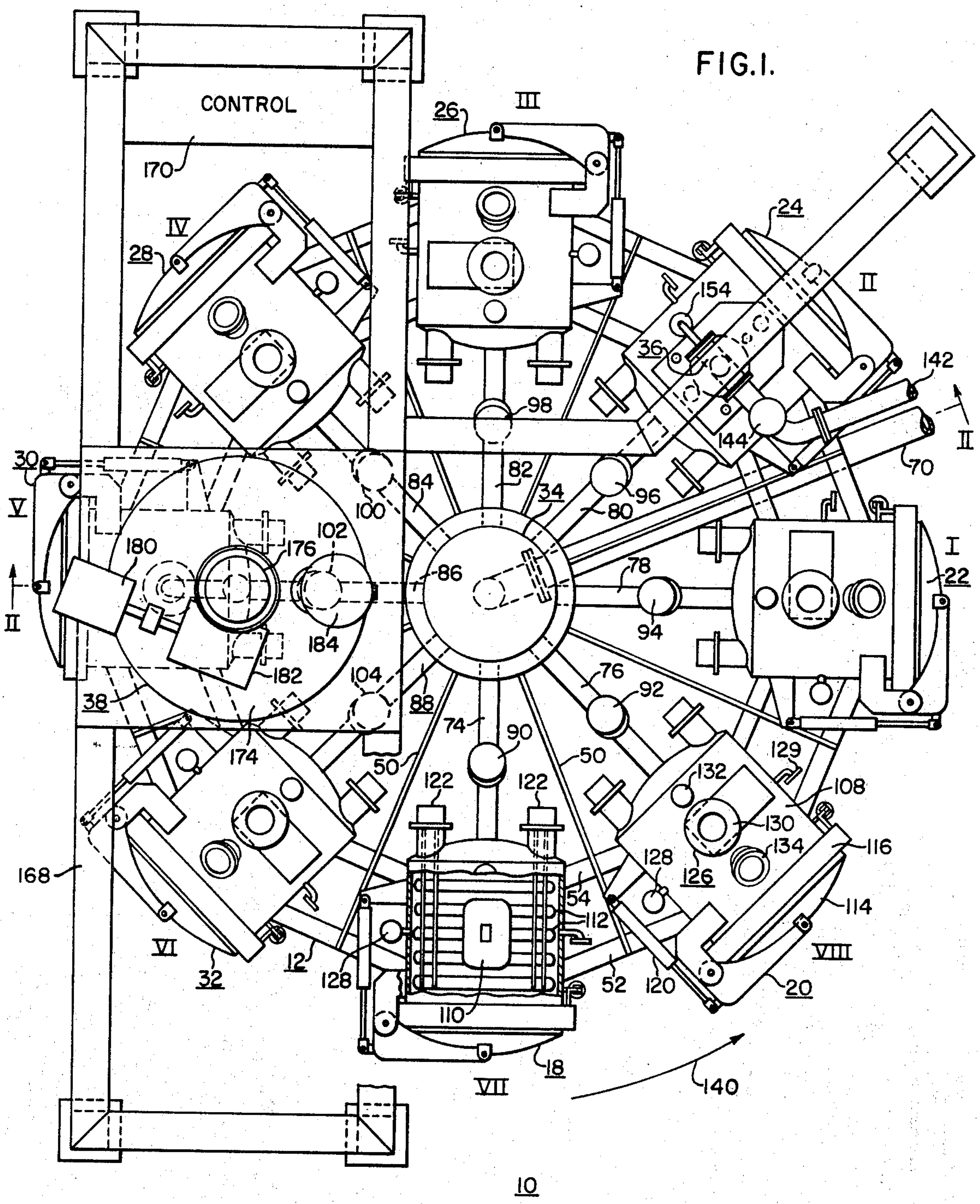
FIG.1.



WITNESSES

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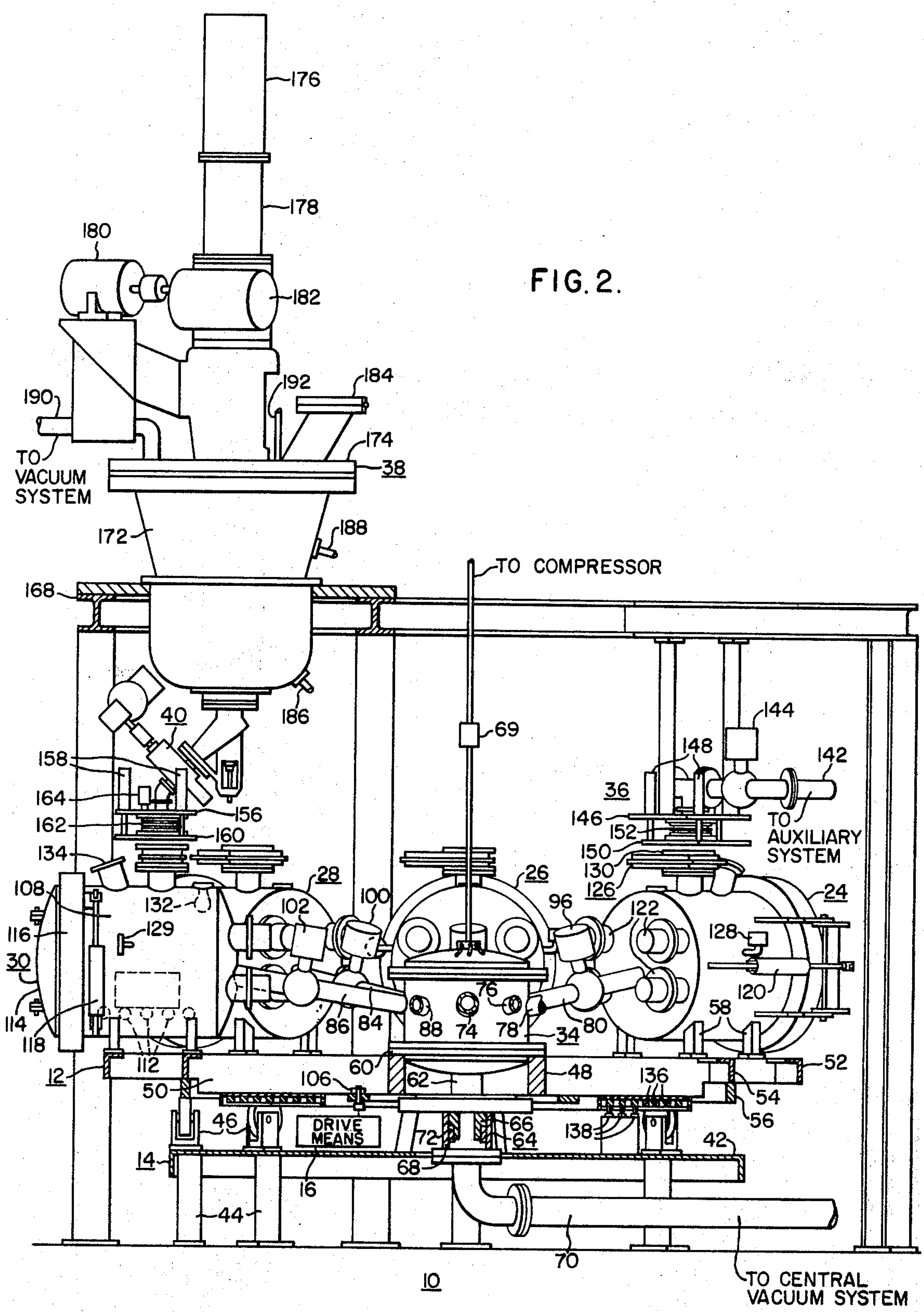
FIG. 2.


176
178
180
182
190
TO VACUUM SYSTEM
192
184
174
38
172
188
TO COMPRESSOR
168
186
40
69
144
148
142
36
158
164
156
162
160
146
152
TO AUXILIARY SYSTEM
150
134
130
126
108
28
26
24
132
100
102
96
122
116
129
128
30
76
120
114
86
84
88
74
78
80
58
118
34
112
60
52
12
48
50
106
62
136
54
56
46
DRIVE MEANS
72
66
64
138
42
14
68
16
44
70
10
TO CENTRAL VACUUM SYSTEM

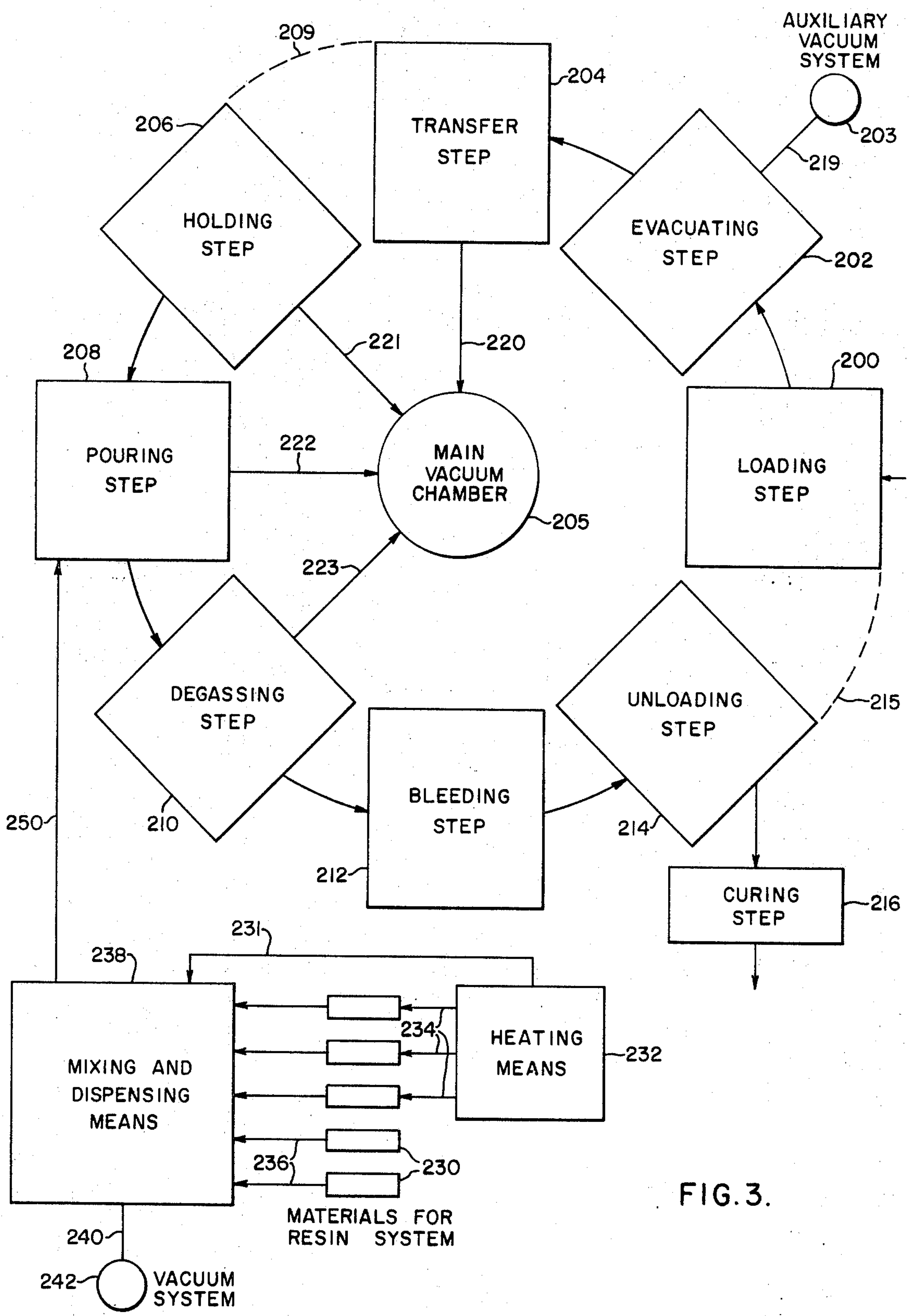

209
204
TRANSFER STEP
AUXILIARY VACUUM SYSTEM
203
219
206
HOLDING STEP
EVACUATING STEP
202
221
220
208
200
POURING STEP
222
MAIN VACUUM CHAMBER
205
LOADING STEP
223
DEGASSING STEP
UNLOADING STEP
215
BLEEDING STEP
250
210
214
212
CURING STEP
216
231
238
MIXING AND DISPENSING MEANS
234
HEATING MEANS
232
236
230
MATERIALS FOR RESIN SYSTEM
240
242
VACUUM SYSTEM

FIG. 3.

United States Patent Office

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CASTING APPARATUS FOR ENCAPSULATING ELECTRICAL CONDUCTORS

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U.S. Cl. 18—5 15 Claims

ABSTRACT OF THE DISCLOSURE

Casting apparatus for at least partially encapsulating electrically conductive means in an insulating resin system. The casting machine or apparatus includes a rotary carriage which supports a plurality of vacuum chambers, and drive means for indexing the carriage. The casting machine includes first and second separate vacuum systems, the first of which is connectable to the vacuum chambers at one of the machine index positions to provide the initial vacuum, and the other of which is permanently connected to each vacuum chamber through a rotary shaft seal, and an individual valve for each vacuum chamber. After the pressure in a vaccum chamber is reduced by the first vacuum system to a magnitude which is substantialy the same as that of the second vacuum system, the first vacuum system is disconected from the vacuum chamber, and the valve is opened to the second vacuum system, thus transferring each vacuum chamber from the first vacuum system to the second vacuum system. Also included is means for sealably introducing a pourable cast resin system into a vacuum chamber and its mold, and valve means for returning each vacuum chamber to atmospheric pressure after the vacuum pouring and degassing steps are completed.

BACKGROUND OF THE INVENTION

Field of the invention

The invention relates to apparatus for at least partially encapsulating electrical conductors, such as coils, windings, and electrical bushing conductor studs, with a pourable cast resinous solid insulation system.

Description of the prior art

Prior art encapsulating methods and apparatus generally operate on the batch principle, wherein molds are introduced into a vacuum chamber, the vacuum chamber is evacuated, the resin system is poured, the chamber is brought back to atmospheric pressure, and the filled molds are removed. While this method and apparatus produces acceptable encapsulated electrical devices, production capabilities are limited due to the length of time required for the various steps of the process. Increasing the number of batch operations to provide the required production rate is not an economical solution, as it is very costly due to the duplication of apparatus, and it requires a large number of operating personnel, as well as extensive floor space. It would be more desirable to provide new and improved apparatus for encapsulating electrical conductors, which substantially increases the production capability of the apparatus, compared with batch type methods, without a correspoding increase in cost, floor space and operating personnel.

SUMMARY OF THE INVENTION

Briefly, the invention discloses new and improved apparatus for casting pourable resin systems, which includes a rotatable carriage having a plurality of vacuum chambers disposed thereon, and drive means for rotating the carriage between predetermined index positions. Each vacuum chamber has a sealable opening adapted for receiving molds, and each vacuum chamber is connected to a central vacuum system by virtue of a rotating shaft seal which allows the vacuum to be brought to a central manifold on the rotatable carriage. Suitable valved piping means from the manifold to each vacuum chamber complete the central vacuum system. Each vacuum chamber also includes a valve which cooperates with an auxiliary vacuum system at one of the index positions, in order to evacuate the vacuum chambers and allow each vacuum chamber to enter the central vacuum system already at the same pressure as the central vacuum system. This valve also cooperates with means for sealingly introducing a resin system into the vacuum chamber and its molds. Another valve is also included on each vacuum chamber for bleeding air into the chambers to return them to atmospheric pressure after the manufacturing steps which require a vacuum have been completed.

BRIEF DESCRIPTION OF THE DRAWINGS

Further advantages and uses of the invention will become more apparent when considered in view of the following detailed description and drawings, in which:

FIG. 1 is a plan view of a casting machine or apparatus constructed according to the teachings of the invention;

FIG. 2 is an elevational sectional view of the casting apparatus shown in FIG. 1, with the section being taken generally along the lines II—II of FIG. 1; and

FIG. 3 is a process flow diagram illustrating a method for casting electrical conductors in accordance with the teachings of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, and FIGS. 1 and 2 in particular, there is shown plan and elevational views, respectively, of new and improved casting apparatus **10** constructed according to the teachings of the invention. In order to more clearly illustrate the construction of the casting apparatus **10**, the elevational view in FIG. 2 is a section taken generally along the lines II—II of FIG. 1. In general, casting apparatus or machine **10** comprises a rotatable carriage **12**, a supporting base **14**, drive means **16** for indexing the rotatable carriage **12**, a plurality of vacuum chambers **18**, **20**, **22**, **24**, **26**, **28**, **30** and **32** disposed in spaced relation on the carriage **12**, a central vacuum system distributable to the various vacuum chambers through manifold means **34**, means **36** connectable to the vacuum chambers for providing an initial vacuum in the vacuum chambers, means **38** for mixing and storing the components of the resin system, and dispensing means **40** for metering and dispensing the resin system into the vacuum chambers at the proper time.

Supporting base **14** may be of any suitable construction, for example, having a structural steel bed **42** which is elevated and supported by a plurality of steel leg members **44**. A plurality of upstanding roller members **46** are disposed on bed **42**, equally spaced about the circumference of a predetermined circle for supporting and allowing rotary movement of the carriage **12**.

Carriage **12** is a substantially circular wheel or spider-like structure, having a steel tubular inner member **48** which forms the "hub" of the wheel, and a plurality of radially extending web portions **50** which are welded to the tubular member **48**. The supporting members for the vacuum chambers, such as vacuum chamber **18**, are formed by welding steel channel members between the plurality of webs **50**, to form two spaced, concentric, substantially ring-shaped supporting members **52** and **54**.

Supporting members **52** and **54** are radially spaced to support the mounting feet of the various vacuum chambers.

Welded to the bottom of the substantially ring-shaped supporting member **54** is a cylindrical ring or bearing member **56** which rests on the plurality of upstanding rollers **46** mounted on the bed **42**.

The vacuum chambers **18, 20, 22, 24, 26, 28, 30** and **32** each have mounting feet, such as feet **58** on vacuum chamber **24**, which are bolted, or otherwise suitably fixed to support members **52** and **54**, with the vacuum chambers being equally spaced about the perimeter of supporting members **52** and **54**.

The vacuum manifold **34** for distributing the vacuum from the main vacuum system (not shown) has a circumferential flange which is bolted to a washer-like plate member **60**, with member **60** being welded to the upper end of the inner tubular member **48**. Manifold **34** extends downwardly through the washer-like member **60**, into the central opening of the inner tubular member **48**, and has a downwardly extending pipe member or conduit **62** which is in communication with the inside of the manifold **34**. Conduit **62** is fixed and sealed to a rotary portion **66** of shaft seal assembly **64**, which performs the functions of radially guiding the carriage assembly **12** and connecting the stationary central vacuum system with the rotatable manifold **34**. The central vacuum system is connected to the stationary portion **68** of the shaft seal assembly **64** via conduit or piping means **70**. A suitable tubular shaft seal **72** is mounted on the internal surface of the stationary portion **68** of shaft seal assembly **64**, and has an inside diameter which snugly fits the rotatable portion **66** of the shaft seal, allowing the portion **66** to rotate, but sealing the shaft against air leakage into the vacuum system. Suitable radial bearings (not shown) are disposed at both ends of the shaft seal **72** in order to guide the carriage **12** when it is being rotated.

The vacuum manifold **34** is connected to vacuum chambers **18, 20, 22, 24, 26, 28, 30** and **32** through radially extending conduit means **74, 76, 78, 80, 82, 84, 86** and **88**, respectively, and each conduit means includes an electrically operated valve for operatively connecting or disconnecting each vacuum chamber with the vacuum manifold **34**, such as valves **90, 92, 94, 96, 98, 100, 102** and **104**, respectively. Thus, each vacuum chamber may be individually and selectively connected to the vacuum manifold **34** and thus to the central vacuum system through its associated electrically operated valve.

Rotatable carriage means **12** is indexed by drive means **16**, which includes air or hydraulically operated cylinder means which successively engage a plurality of spaced pins on the carriage **12**, such as pin **106**, to move the vacuum chambers through a plurality of index positions. Since in this embodiment of the invention there are eight vacuum chambers, each index of the drive means **16** will be arranged to rotate the carriage 45 degrees. The various processing steps for encapsulating the electrical conductors in solid resinous insulation are performed at various index positions, as will be hereinafter explained.

Each of the vacuum chambers **18, 20, 22, 24, 26, 28, 30** and **32** are similar in construction, having a vacuum chamber formed by a substantially cylindrical housing **108** which has its axis horizontally disposed, with housing **108** having an open end which faces radially outward for receiving the mold which is to be filled with the resin system, such as the mold **110** shown in vacuum chamber **18**. Vacuum chamber **18** is shown partially cut away in FIG. 1 to illustrate the mold **110** and the support rails **112** for holding the mold **110** in the vacuum chamber.

The open end of housing **108** is closed by a door **114**, which is sealed by turning a locking ring **116**. Locking ring **116** may be automatically actuated by an air cylinder, such as cylinder **118**, and the door **114** may be opened and closed by an air cylinder, such as cylinder **120**.

The vacuum chamber may be heated by a plurality of heaters at certain times during the processing cycle, such as electrically operated heaters **122**, shown most clearly on vacuum chamber **18** in FIG. 1. However, in most applications auxiliary heat is not required, and heat transfer through the vacuum is so poor that very little heat is lost from the initially heated electrical conductor to be encapsulated, and from the heated resin system once it is poured.

Each vacuum chamber also has two valves, a gate valve **126**, mounted on the top of the housing **108**, and a bleed valve **128** mounted at any convenient location on the housing **108**. The gate valve **126**, which may be operated by an air cylinder, has a flat upper plate **130** which has a suitable opening therein, with a groove and O-ring combination surrounding the opening such that the O-ring extends slightly above the surface of the plate **130**. Thus, as will be hereinafter explained, when access to the internal portion of the vacuum chamber is to be obtained through the gate valve **126**, the opening of the gate valve may be sealed by a flat plate pressed against the plate **130** and its sealing O-ring.

Bleed valve **128**, which may be electrically operated, provides the function of bleeding air into the vacuum chamber after it has been effectively disconnected from the vacuum manifold **34** by its associated main or central vacuum system valve, such as valve **96** associated with vacuum chamber **24**, when it is desired to return the vacuum chamber to atmospheric pressure, to allow door **114** to be opened and the mold **110** to be removed therefrom.

The vacuum chamber may also include a light disposed within housing **108**, such as light **132** shown in vacuum chamber 30 in FIG. 2, and a sight port **134** which allows visual inspection by an operator such as during the filling of the mold **110** with the resinous insulating system. A vacuum gauge **129** may also be disposed on the outside of each vacuum chamber so that an operator can readily determine the condition of the vacuum in the chamber.

In addition to continuously providing a vacuum to the rotatable carriage **12** from a stationary central vacuum system, it is also necessary to provide electrical power to the carriage **12** for the operation of the various valves, limit switches, lights, control functions, and the electrical heaters, if used. This is accomplished by a plurality of concentrically disposed electrically conductive rings **136**, formed of a material such as copper, which are insulatingly mounted to the carriage **12**, and which are accessible from below. Brushes **138** are insulatingly mounted on the stationary bed **42**, and disposed to contact the rings **136**. Thus, electrical power is transferred through the brushes to the rings, with the source of electrical potential being connected to the brushes **138** and the various control functions being connected to the rings **136**.

It is also necessary to provide a supply of air to the rotary portion of the casting apparatus **10**, and this may be provided by an electrically operated compressor disposed on the carriage **12**, or as shown in FIG. 2 it may be provided from a stationary source of air through a rotary air seal **69** and air conduit which may enter the carriage **12** along its vertical axis.

According to the teachings of the invention, each vacuum chamber, such as vacuum chamber **18**, is permanently connected to the central vacuum system through individual valves, such as valve **90**. A vacuum chamber cannot directly "enter" the central vacuum system while it is itself at atmospheric pressure, however, as it would immediately increase the pressure in all of the vacuum chambers which are operatively connected to the central vacuum system. Therefore, after loading a mold into a vacuum chamber and closing and sealing the door, the vacuum chamber must be brought down to substantially the same pressure or vacuum as that of the central system, to allow its central system valve to be opened without adversely affecting the central vacuum system. This may be conveniently accomplished at the index position which follows the loading position. For convenience, the index positions in FIG. 1 are indicated with Roman numerals I through VIII. Thus, in FIG. 1 if it is assumed that index position I is the "load" index position, and the index rotation is counterclockwise as indicated by arrow **140**, then index position II is the index position at which the vacuum chambers may be initially evacuated with an auxiliary vacuum system. Accordingly, as shown in FIGS. 1 and 2, means **36** is provided at index position II for evacuating the vacuum chambers, such as vacuum chamber **24**, while they are at this index position. Means **36** includes a conduit **142** which is connected to the auxiliary vacuum pump (not shown), a valve **144**, which may be electrically operated, for opening and closing conduit **142** as desired, a stationary horizontally disposed mounting plate **146** which contains a plurality of air cylinders **148** mounted transversely to the plate, and having their operating rods downwardly disposed and connected to a movable plate member **150** through a flexible bellows-like coupling **152**. Thus, when vacuum chamber **24** is in index position II, its central system vacuum valve **96** should be closed, and auxiliary vacuum valve **144** should be closed. The air cylinders **148** may then be actuated to lower plate **150**, which has an opening therein, against plate **130**, with the opening in plate **150** being aligned with the opening in plate **130**. The O-ring on the upper surface of plate **130** will be compressed by plate **150**, forming a vacuum tight seal. Gate valve **126** on vacuum chamber **24** may then be opened, followed by the opening of the auxiliary vacuum valve **144**. When vacuum chamber **24** is evacuated to the desired pressure, which will usually be in the range of 1–5 mm. of mercury, the gate valve **126** may be closed, followed by the closing of auxiliary valve **144**. In order to release the vacuum which will still exist between the two valves **126** and **144**, a bleed valve **154**, shown in FIG. 1 is opened before the cylinders **148** are actuated to lift the plate **150**. As soon as the gate valve **36** on vacuum chamber **24** has closed, following the initial evacuation, the valve **96** to the central vacuum system may be opened. This may be conveniently accomplished with a limit switch upon the indexing of vacuum chamber **24** to index position III. Since the air in the mold and its contents, i.e., the electrical conductors to be encapsulated, may have entrapped air which was not completely removed by the auxiliary vacuum system at index position II, the next two index positions III and IV, in this embodiment of the invention, are used to allow the central vacuum system to remove as much trapped air as possible from the vacuum chambers prior to the pouring of the resin system, maintaining the vacuum in the range of 1–5 mm. of mercury.

After the vacuum chamber and its contents have been under the vacuum for a sufficient length of time to insure removal of substantially all entrapped air, the pourable cast resin system may be introduced into the vacuum chamber and its mold (or molds). As shown in FIGS. 1 and 2, this is accomplished at index position V. The resin system, which has been mixed under vacuum in mixer **38** and held at a predetermined elevated temperature therein, is introduced into the vacuum chamber at index position V, using the same gate valve previously used to provide the initial evacuation. For example, as shown in FIGS. 1 and 2, vacuum chamber **30** is in index position V and the mixer **38** and dispenser **40** are mounted overhead, connected to a sealing arrangement similar to the one used by the auxiliary vacuum system in making the vacuum tight seal with the gate valve **126**. The dispensing means **40** has its output end connected through an opening in a horizontally disposed mounting plate **156**, which has air cylinders **158** mounted thereon, with the cylinder rods extending downwardly and connected to a plate member **160** which has an opening therein. The openings in plate members **156** and **160** are sealed and interconnected by flexible bellows **162**. Thus, when it is desired to introduce the resin system into a vacuum chamber, the air cylinders **158** are actuated, to lower plate **160** against plate **130** to compress its O-ring, and seal the connection between the dispensing means **40** and the vacuum chamber **30**. Gate valve **126** may then be opened and dispensing means **40** may meter a predetermined amount of the resin system into the mold contained under vacuum in the vacuum chamber.

When the desired amount of material is metered into the mold, the dispensing means **40** will close its output end, and gate valve **126** may then be closed. Before the cylinders **158** are actuated to lift the plate member **160**, bleed valve **164** is opened to release the vacuum between dispensing means **40** and gate valve **126**.

The central vacuum system valve is kept open as the carriage **12** is indexed into position VI and while it is in this position, in order to remove any gases from the poured resin which were not removed during the vacuum mixing process.

As the carriage is again indexed, the central vacuum system valve, such as valve **90** on vacuum chamber **18**, closes, and then the bleed valve **128** on the vacuum chamber is opened to slowly bring the vacuum chamber back to atmospheric pressure. When the carriage is indexed again, the filled mold may be removed at index position VIII, by first actuating cylinder **118** to unlock and unseal the door, and by actuating cylinder **120** to open the door. The mold may then be removed and put through a predetermined curing cycle to gell and cure the cast resin system.

A complete cycle of casting machine **10** will now be described starting with the vacuum chamber **22** at index position I. Index position I, in this embodiment of the invention, is a load position. Vacuum chamber **22** will index into this position with its door **114** open, and with gate valve **126**, bleed valve **128**, and central vacuum system valve **94**, closed. The mold **110**, along with its electrical conductors to be encapsulated, is placed into the vacuum chamber. The loading may be accomplished automatically, such as with a hydraulically operated push rod, and the door **14** may be automatically closed by cylinder **120**, and sealed and locked by air cylinder **118** being actuated to turn locking ring **116**. The mold and the electrically conductive members disposed therein are pre-heated to approximately the temperature at which the resin system will be poured, usually in the range of 80° C. to 110° C. The time that casting machine **10** will remain at each index position will be determined by the longest processing step, and this will depend upon the specific application. For example, in the encapsulation of transformer coils, such as disclosed in co-pending application Ser. No. 675,840, filed Oct. 17, 1967, which application is assigned to the same assignee as the present application, in an eight vacuum chamber casting machine the pouring of the resin would usually require the longest time, setting the index time at approximately two minutes. If the electrical conductors to be encapsulated require less resin, such as small electrical bushings, then the pouring time, and thus the cycle time, may be substantially reduced. Where smaller devices are to be encapsulated, more than one mold may be placed in each vacuum chamber, if desired.

After loading in index position I, the carriage **12** is indexed 45° by drive means **16**, bringing vacuum chamber **22** to index position II and to the initial evacuation step of the process via the auxiliary vacuum system. The gate valve **126** of vacuum chamber **22** will stop directly under the flexible coupling of the auxiliary vacuum system, and air cylinders **148** will be automatically actuated to lower plate **150** against plate **130** of the gate valve **126**, sealing the connection. The gate valve **126** is then automatically opened and valve **144** will then open to evacuate the vacuum chamber to a predetermined value. After the evacuation of the vacuum chamber, valve **144** will close, gate valve **126** will close, bleed valve **154** will open to release the vacuum between valves **126** and **144** and then it will close, and cylinder **148** will lift plate **150**.

Vacuum chamber **22** will then be indexed to position III, and while indexing, its valve **94** may be automatically opened. For example, it may be signalled by a micro-switch operated by the movement of the carriage. The vacuum in vacuum chamber **22** will be continuously held at both index positions III and IV, with no processing at these two positions. The time provided by these two vacuum holding stations insures that substantially all air entrapped in the mold and the electrical conductors to be encapsulated will be removed. From index position IV, vacuum chamber **22** will be indexed into position V, which is where the pouring of the resin takes place. As the vacuum chamber is indexed into this position, the operator may visually check vacuum gauge **129** to insure that the vacuum is in the proper range for pouring. The pouring step may be automatic, or the operator may control it manually. Cylinders **158** are actuated to press plate **160** against plate **130** of the gate valve, the O-ring in the face of plate **130** will seal the connection, gate valve **126** will open, and dispensing means **40** will be actuated to meter a predetermined amount of resin from mixer means **38** into the mold. The dispensing means **40** will then close its outlet, gate valve **126** will close, bleed valve **164** will open to release the vacuum between the dispensing means **40** and the gate valve **126** and cylinders **158** will lift plate **160** to break the coupling.

Although the resin system is vacuum mixed in mixer **38**, as will be hereinafter described, it is necessary to degas the poured resin system. Index position VI is used to perform the degassing step. Thus, when chamber **22** is indexed into position VI, its central vacuum system valve **94** will remain open, and entrapped air will continue to be removed from the poured resin system for the duration of this index position.

Vacuum chamber **22** will then be indexed into position VII. At this position, its central vacuum valve **94** will close and bleed valve **128** will open to slowly bring vacuum chamber **22** back to atmospheric pressure. Casting machine **10** will then index vacuum chamber **22** into position VIII, where the filled mold or molds may be automatically or manually removed. Upon indexing into position VIII, cylinder **118** will be actuated to rotate the locking ring **116** and cylinder **120** will be actuated to open the door **114**. The filled molds are ready for the specific cure cycle of the particular resin system used.

The control for logically coordinating the signals from the various limit switches, valves cylinders, micro-switches and the like, to insure that all of the functions at each index position have been performed before the drive means **16** indexes the machine to the next position, may be conventional, and is therefore shown generally at **170**.

The mixer **38** is mounted on a suitable structural steel framework **168** above the rotatable portion of the casting machine **10**, and it includes a hollow tank or body portion **172**, which has an opening at its lower end in sealed communication with dispensing means **40**, and a top portion **174** which seals the upper end of the mixer tank **172**. The mixer tank **172** includes relatively large low speed mixer blades (not shown) and smaller, high speed mixer blades (not shown) driven by co-axial drive shafts disposed vertically through the top portion **174**. The high speed drive shaft is coupled directly to motor **176** via coupling **178**, and low speed drive shaft is connected to motor **180** through a reduction gear **182**.

Any suitable castable resin system may be used to encapsulate the electrical conductors, such as those of the thermoplastic, or thermosetting types. For purposes of example, however, it will be assumed that the resin system is thermosetting and of the epoxy type. Co-pending application Ser. No. 456,038, filed May 6, 1965, now abandoned, discloses an excellent epoxy resin system that may be used, including an epoxy resin system having an epoxy equivalent weight of about 150–450, an anhydride resin curing agent, a resin curing accelerator, and powdered beryl as the filler. A suitable thixotropic agent may also be added to prevent settling of the filler system. Other excellent epoxy resin systems which may be used are disclosed in applications Ser. Nos. 447,237, now abandoned, and 645,319, now U.S. Pat. 3,433,893, filed Apr. 12, 1965 and June 12, 1967, respectively, with all of these co-pending applications being assigned to the same assignee as the present application.

A sealable port or opening **184** is shown in FIGS. 1 and 2 for introducing the components of the resin system, but it is to be understood that the components may be automatically metered and/or weighed and automatically introduced in the mixer **38**, if desired. The epoxy resin, its curing agent, and accelerator, are all pre-heated to a predetermined temperature, such as between 80° C. to 105° C., at which temperature they are fluid, and they may be accurately metered and pumped into the mixer tank. The filler and any thioxtropic agent, if used, will be solid, and may be automatically weighed and transferred to the mixer tank **172** through a sealable opening or openings.

Mixer **38**, as shown, mixes all of the components of the resin system, thus providing a predetermined limited period of time in which the resin system must be used. It would be equally suitable to divide the resin system into two parts, in which the epoxy resin and its curing agent are separated. Each part would be completely mixed and held in a heated tank, and they would only be mixed together when required. Therefore, the two portions of the system may be held indefinitely, and only mixed when required by the casting machine.

Since the components of the resin system must be mixed and held at a predetermined elevated temperature, the mixer tank **172** may contain heating passages through which a heated liquid, such as ethylene glycol, may be circulated. Pipes **186** and **188** indicate the entrance and exit ends of the passages through the jacket of the mixer tank, respectively.

It is essential that the components of the resin system be at least mixed while under a vacuum, such as a vacuum of 1–5 mm. of mercury, in order to facilitate the removal of as much air as possible from the system before pouring. If the resin system is not outgassed prior to pouring in the vacuum chamber, splattering of the resin system will occur when it is poured into the evacuated chamber. Pipe **190** indicates the connection of a vacuum system to the mixer tank **172**. This vacuum system may be a separate vacuum system, or the auxiliary vacuum system used to provide the initial evacuation of the vacuum chambers may be used.

After mixing the components of the resin system in mixer **38**, the mixed resin system may be held under vacuum; or the mixing chamber may be brought back to atmospheric pressure. Once the system is mixed under vacuum, it may be returned to atmospheric pressure and it will absorb very little air. The disadvantage of the system entrapping a small amount of air after mixing, may be offset by the easier transfer of the resin system from the tank **172** to the molds in the vacuum chambers, when the mixing chamber is at atmospheric pressure.

When the mixed resin system in tank **172** has been completely used, the tank may be cleaned before mixing the next batch of resin. Pipe **192** is for connection to a supply of a suitable cleaning fluid, such as trichloroethylene.

Dispensing means **40** may be a motor and pump combination which will pump and meter the resin system from the tank **172** when it is desired to fill a mold.

FIGS. 1 and 2 illustrate a new and improved casting machine for encapsulating electrical devices in a pourable resin system, according to a new and improved method of substantially continuous casting, which greatly increases the production rate over prior art methods, while reducing the required number of operating personnel. FIG. 3 is a flow diagram which illustrates this method, characterized by the use of a rotary vacuum machine, which utilizes two independent vacuum systems. The flow diagram is shown with general reference to the casting machine **10** shown in FIGS. 1 and 2 in order to illustrate the basic steps of the method and how the casting machine **10** could be arranged to form other embodiments within the scope of the invention.

The first step of the casting method, illustrated by block **200**, is the loading of a mold into a vacuum chamber of a rotary casting machine having a plurality of vacuum chambers. The next step of the method, illustrated by block **202**, is the evacuation of the vacuum chamber by a first or auxiliary vacuum system, illustrated by line **219** and circle **203**. The next step is the transferring of the vauuum chamber from the first vacuum system **203** to a second or main vacuum system, indicated by the line **220** and circle **205**. The next step is the holding of the vacuum chamber at a predetermined vacuum, illustrated by block **206** and line **221**. Since the transferring and holding steps may be combined into one operation, instead of using two independent index positions of the rotary vacuum casting machine, steps **204** and **206** are shown jointed by a dotted line **209**. In other words, instead of having two index positions on the casting machine **10** between the evacuating step and the pouring step, it would be entirely practical to utilize only one index position. The time that the electrical conductors to be encapsulated are under vacuum before pouring is determined by the application, as the longer the time under vacuum, the less chance there will be of insulation failure due to air bubbles in the insulation. The next step is the vacuum pouring of the resin system, indicated by block **208** and line **222**. The next step is the degassing step, indicated by block **210** and line **223**, for removing entrapped air from the poured resin system. The next step is the bleeding step, indicated by block **212**, during which the vacuum chamber is brought back to atmospheric pressure. The next step is the unloading of the mold from the vacuum chamber, indicated by block **214**. Since the loading and unloading of the mold may occur at the same index position of the rotary casting machine, the unloading and loading steps **214** and **200** are shown joined by dotted line **215**. The filled molds are then ready for the curing step, indicated by block **216**.

The resin system may be prepared by providing the materials which are to be combined into the resin system, indicated by block **230**, heating certain of the materials to a predetermined elevated temperature, with suitable heating means illustrated by block **232** and line **234**, introducing the material into the mixing and dispensing means, illustrated by lines **236** and block **238**, mixing the materials under vacuum, illustrated by line **240** and circle **242**, heating the mixed materials, indicated by line **231** and block **232**, and dispensing the mixed system to initiate the pouring step **208**, indicated by line **250**.

In summary, there has been disclosed a new and improved method of substantially continuously casting a pourable resin system about electrical conductors, such as electrical windings, in a rotary vacuum casting machine which utilizes two separate vacuum systems. The method includes the steps of loading a mold which contains the electrical conductors to be encapsulated in a vacuum chamber, evacuating the vacuum chamber with a first vacuum system, transferring the vacuum chamber to a second vacuum system, pouring a resin into the mold while the vacuum chamber is connected to the second vacuum system, degassing the poured resin with the second vacuum system, bleeding air into the vacuum chamber to bring it back to atmospheric pressure, unloading the filled molds from the vacuum chambers, and curing the resin system.

Also disclosed is a new and improved rotary casting machine having a plurality of vacuum chambers, which is suitable for performing the steps of the new casting method. The machine indexes through a plurality of predetermined index positions, performing the different manufacturing steps at predetermined index positions, which allows one machine and one operator to produce encapsulated electrical devices at rates only achievable in prior art by utilizing a plurality of separate casting machines and a plurality of operators.

Since numerous changes may be made in the above described apparatus and different embodiments of the invention may be made without departing from the spirit thereof, it is intended that all matter contained in the foregoing description or shown in the accompanying drawings, shall be interpreted as illustrative, and not in a limiting sense.

We claim as our invention:

1. A casting machine for at least partially encapsulating electrically conductive means in a resin system, comprising:

movable support means,

a plurality of vacuum chambers disposed on said movable support means, said vacuum chambers each having a sealable opening adapted for receiving at least one mold which contains the electrically conductive means to be encapsulated,

drive means for indexing said movable support means to move said vacuum chambers successively through a plurality of index positions,

first vacuum means connectable to a vacuum chamber at one of said index positions, for providing a vacuum in the vacuum chamber after a mold is introduced therein,

second vacuum means,

first valve means connecting each of said plurality of vacuum chambers to said second vacuum means, said first valve means operably connecting certain of said vacuum chambers to said second vacuum system to maintain the vacuum provided by said first vacuum means,

means for sealingly introducing a resin system into a vacuum chamber at an index position at which the vacuum chamber is operatively connected to said second vacuum means, for filling the mold, and

means for bringing the vacuum chamber back to atmospheric pressure, to allow filled molds to be removed from the sealable openings in the vacuum chambers at one of the index positions.

2. The casting machine of claim **1** wherein the movable support is a rotatable carriage and including a rotary shaft vacuum seal, wherein the plurality of vacuum chambers are connected to the second vacuum means through the rotary shaft seal.

3. The casting machine of claim **1** including means for electrically heating each of the vacuum chambers.

4. The casting machine of claim **3** wherein the movable support is a rotatable carriage and including a plurality of electrically conductive rings insulatingly mounted on said rotatable carriage, stationary brushes adapted for connection to a source of electrical potential, and means electrically connecting the electrically conductive rings to the means for electrically heating the vacuum chambers.

5. The casting machine of claim **1** wherein each of the vacuum chambers includes a gate valve to which the first vacuum means is connectable at one of the index positions, and through which the resin system is sealingly introduced into the vacuum chamber at another of the index positions.

6. The casting machine of claim **1** wherein the plurality of index positions includes at least one position for unloading and loading molds, an index position at which said first vacuum means is connectable to provide a vacuum in the vacuum chambers, an index position at which the resin system is introduced while the vacuum is being maintained by the second vacuum means, and an index position at which the vacuum chamber is brought back to atmospheric pressure.

7. The casting machine of claim 1 wherein the means for sealingly introducing the resin system into the vacuum chamber is evacuated to substantially the same pressure as the vacuum chamber which it is to service.

8. The casting machine of claim 1 wherein the means for sealingly introducing the resin system into the vacuum chamber includes a sealable mixing chamber for mixing the materials of the resin system, heating means for heating the materials to a predetermined temperature, vacuum means for evacuating the mixing chamber, at least while the materials are being mixed, and dispensing means for measuring and dispensing the mixed resin system.

9. A casting machine for at least partially encapsulating electrical conductive means in a resin system, comprising:

a plurality of vacuum chambers each having sealable openings adapted for receiving molds which contain the electrically conductive means to be encapsulated, and first valve means,

a first vacuum system connectable to the first valve means on said vacuum chambers for providing a predetermined vacuum in each vacuum chamber after it has received a mold,

a plurality of second valve means,

a second vacuum system connected to said plurality of vacuum chambers through said plurality of second valve means, respectively, for maintaining the predetermined vacuum in the vacuum chamber provided by said first vacuum system, and

means adapted for sealingly introducing a resin system into a vacuum chamber through said first valve means, while the vacuum in the chamber is being maintained by said second vacuum system.

10. The casting machine of claim 9 including rotatable carriage means, and drive means for indexing said carriage means, with the plurality of vacuum chambers being disposed on said carriage means.

11. The casting machine of claim 10 including a rotary vacuum shaft seal for sealably connecting the second vacuum system to the plurality of vacuum chambers on the rotatable carriage means.

12. The casting machine of claim 11 including third valve means disposed on each of the plurality of vacuum chambers for bringing the vacuum chambers back to atmospheric pressure after the resin system has been introduced into the mold, and the second valve means has closed.

13. The casting machine of claim 12 wherein the drive means successively indexes the vacuum chambers through a plurality of index positions, including positions for unloading and loading molds, providing a vacuum with the first vacuum system, introducing the resin system into the mold while the vacuum is being maintained by the second vacuum system, and returning the vacuum chambers to atmospheric pressure with the third valve means.

14. The casting machine of claim 9 wherein the means for sealingly introducing the resin system into the vacuum chamber is evacuated to substantially the same pressure as the vacuum chamber which it is to service.

15. The casting machine of claim 9 wherein the means for sealingly introducing the resin system into the vacuum chambers includes a sealable mixing chamber for mixing the materials of the resin system, heating means for heating the materials to a predetermined temperature, vacuum means for evacuating the mixing chamber, at least while the materials are being mixed, and dispensing means for measuring and dispensing the mixed resin system.

References Cited

UNITED STATES PATENTS

1,457,290	5/1923	Schroeder	18—20
1,900,456	3/1933	Mead	18—20
1,969,323	8/1934	Person	18—20
2,414,525	1/1947	Hill et al.	264—102
2,672,652	3/1954	Howe et al.	18—20
2,876,492	3/1959	Frieder et al.	18—26
3,267,517	8/1966	Altermott	18—26
3,381,339	5/1968	Trelease	18—26

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