United States Patent

Charman, Jr. et al.

[15] **3,697,631**

[45] **Oct. 10, 1972**

[54] **METHOD AND APPARATUS FOR FORMING A MEMBER FROM AN EXCESS SLURRY OF REFRACTORY MATERIAL**

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[21] Appl. No.: **875,276**

[52] **U.S. Cl.** **264/37,** 162/228, 162/396, 264/87, 425/84, 425/218

[51] **Int. Cl.**.....**B22c 15/22,** D21j 3/00

[58] **Field of Search**.....162/382, 383, 393, 387, 394, 162/395, 396, 399, 407, 228, 253, 256, 252, 218, 385; 264/86, 87, 37; 425/89, 84, 218; 164/7, 33, 160

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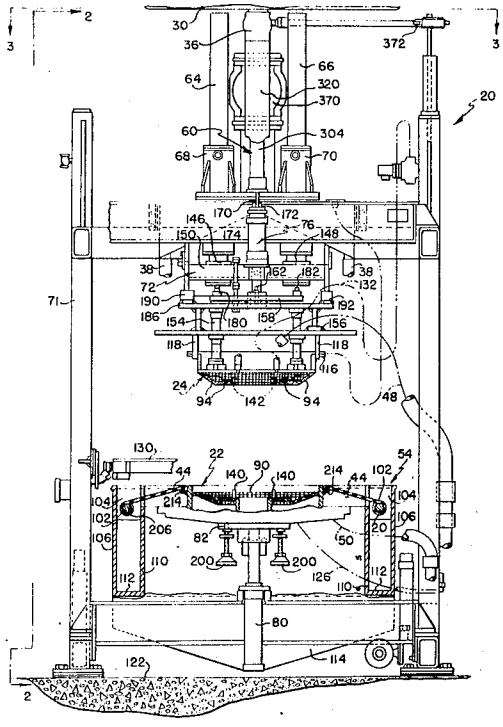
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[57] **ABSTRACT**

An improved machine or apparatus for forming member from a slurry of refractory material includes a pair of mold sections which cooperate to form a cavity. A flexible diaphragm extends around the mold sections and is movable to an inwardly and downwardly sloping position to form a trough connected in fluid communication with the mold cavity. The mold cavity is flooded by filling the trough with the slurry of refractory material. Water is then drawn from the slurry in the mold cavity to form a wet-cake of refractory material. The water content of this wet-cake of refractory material is at least partially controlled with an adjustable timer which regulates the length of time for which water is drawn from the mold cavity. After sufficient refractory material has been deposited in the mold cavity to form a wet-cake having the shape of the member to be formed, the diaphragm is moved to an outwardly and downwardly sloping position to enable excess slurry to flow away from the mold sections and into a receptacle. The excess slurry is pumped from this receptacle to a main mixing or batch tank where it is mixed with a relatively large quantity of the slurry. Therefore, when this excess slurry is subsequently reused, it will have a water content or consistency corresponding to that of the main batch of slurry.

31 Claims, 15 Drawing Figures



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SHEET 1 OF 7

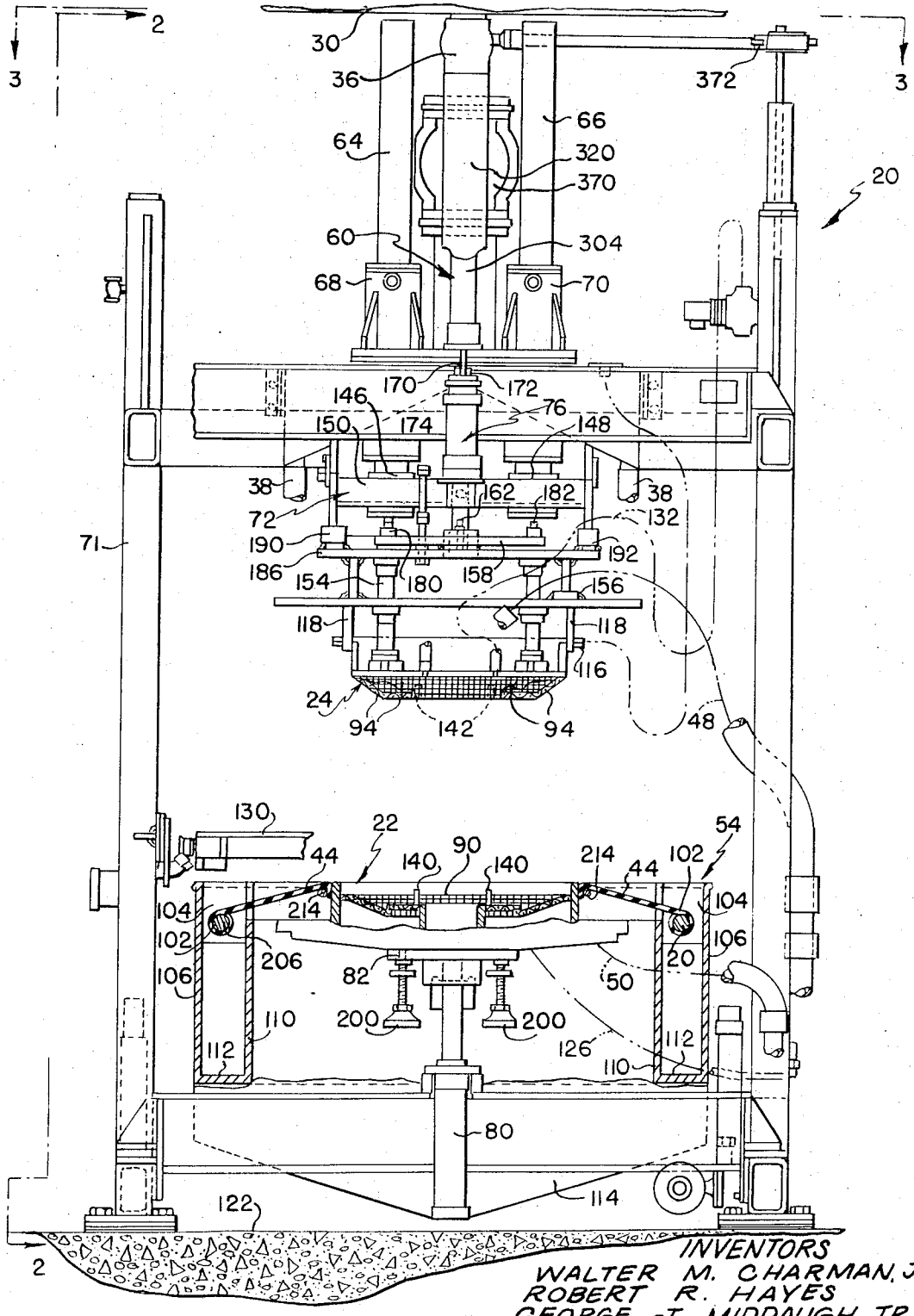


FIG. 1

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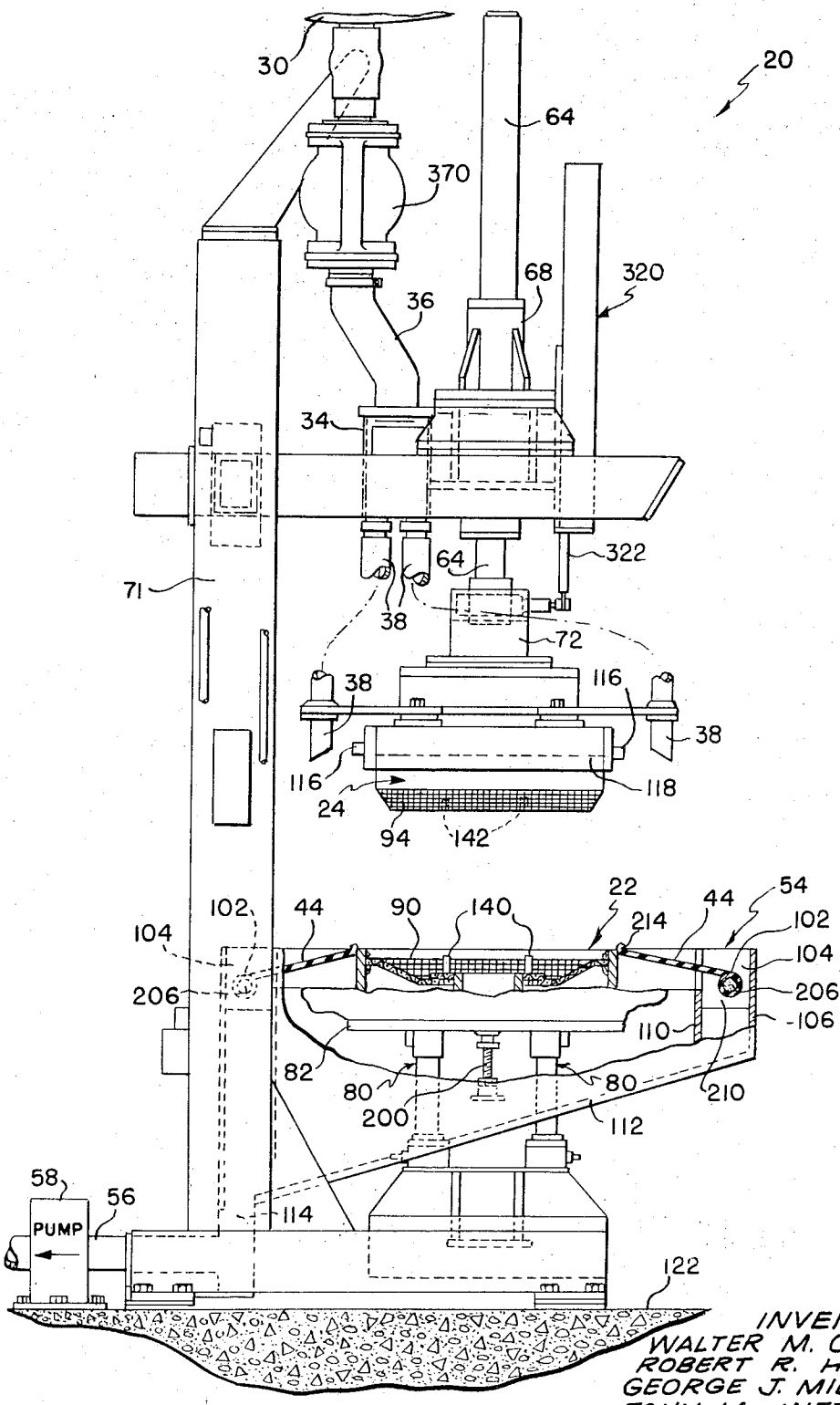
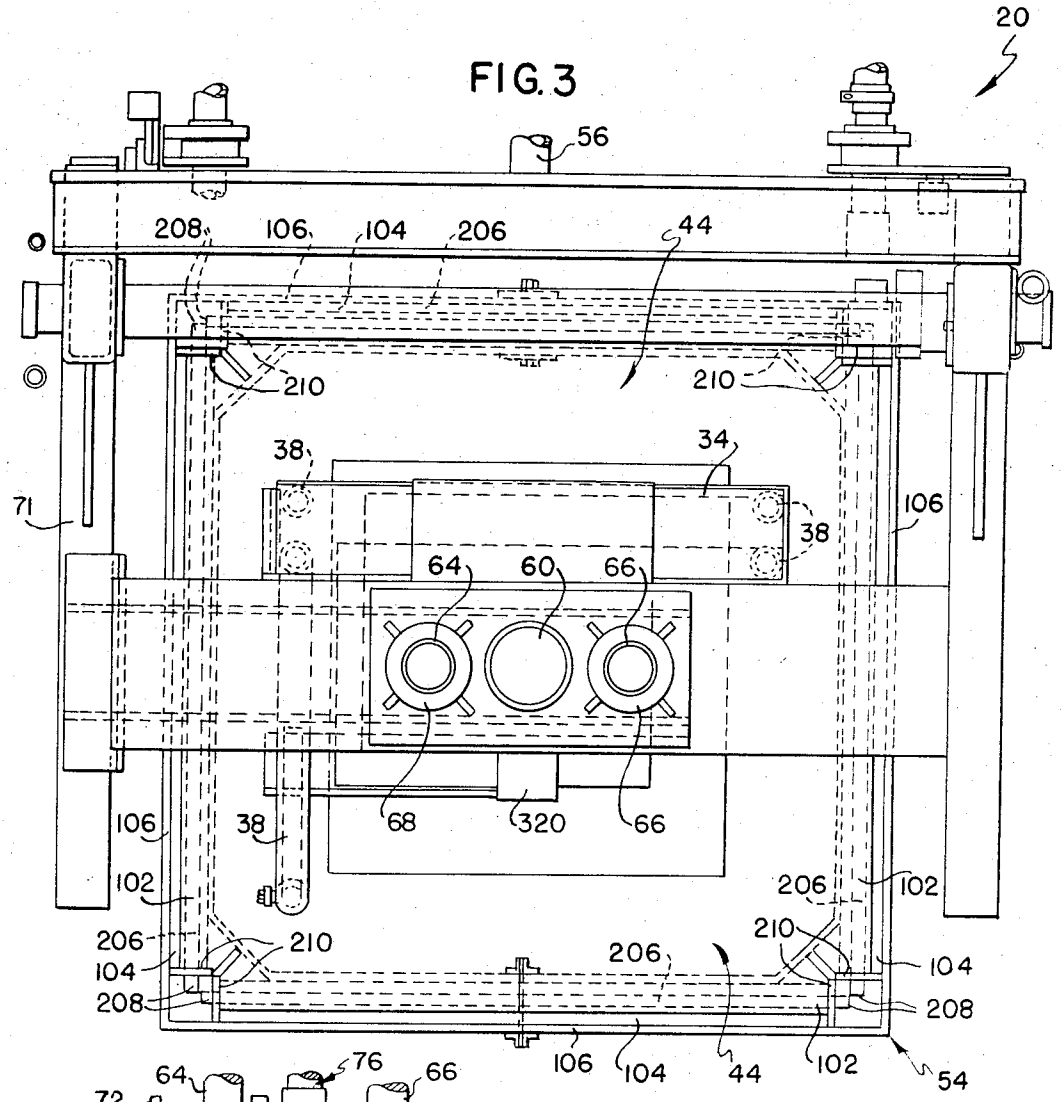


FIG.2

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FIG. 3



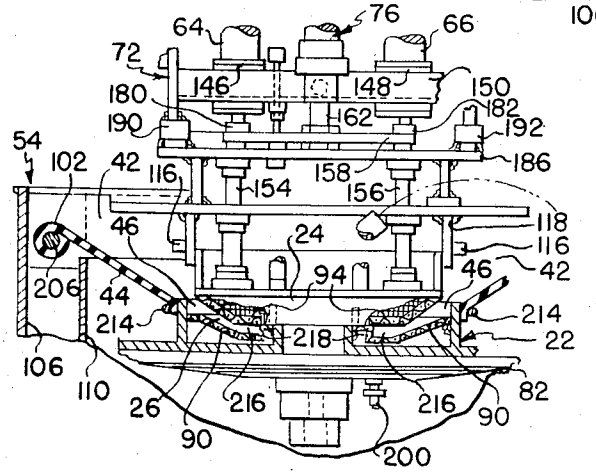


FIG. 4

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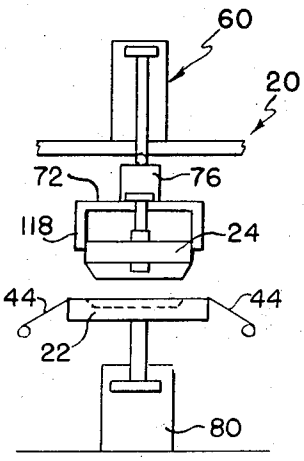


FIG.5

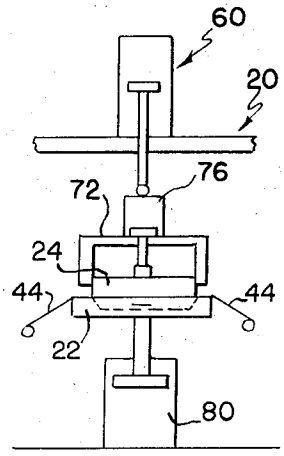


FIG.6

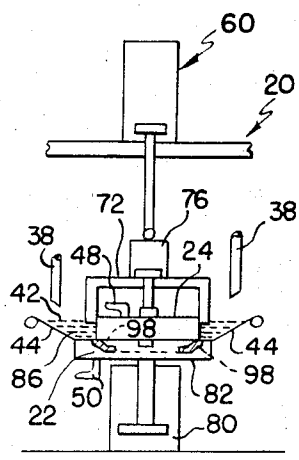


FIG.7

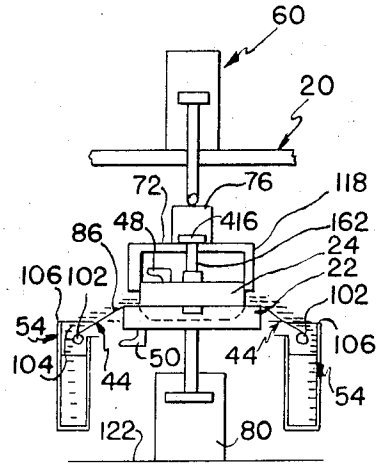


FIG.8

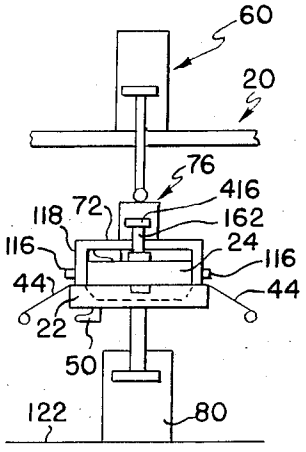


FIG.9

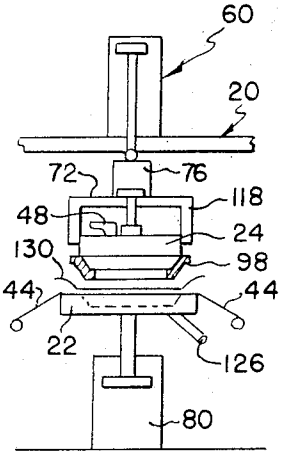


FIG.10

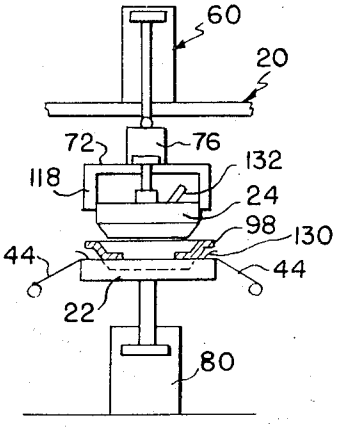


FIG.11

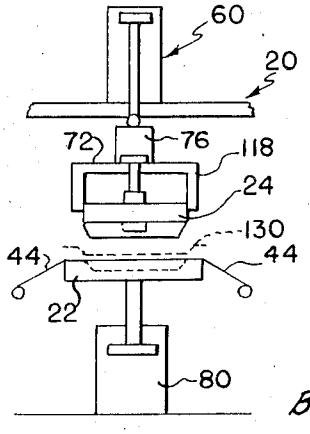


FIG.12

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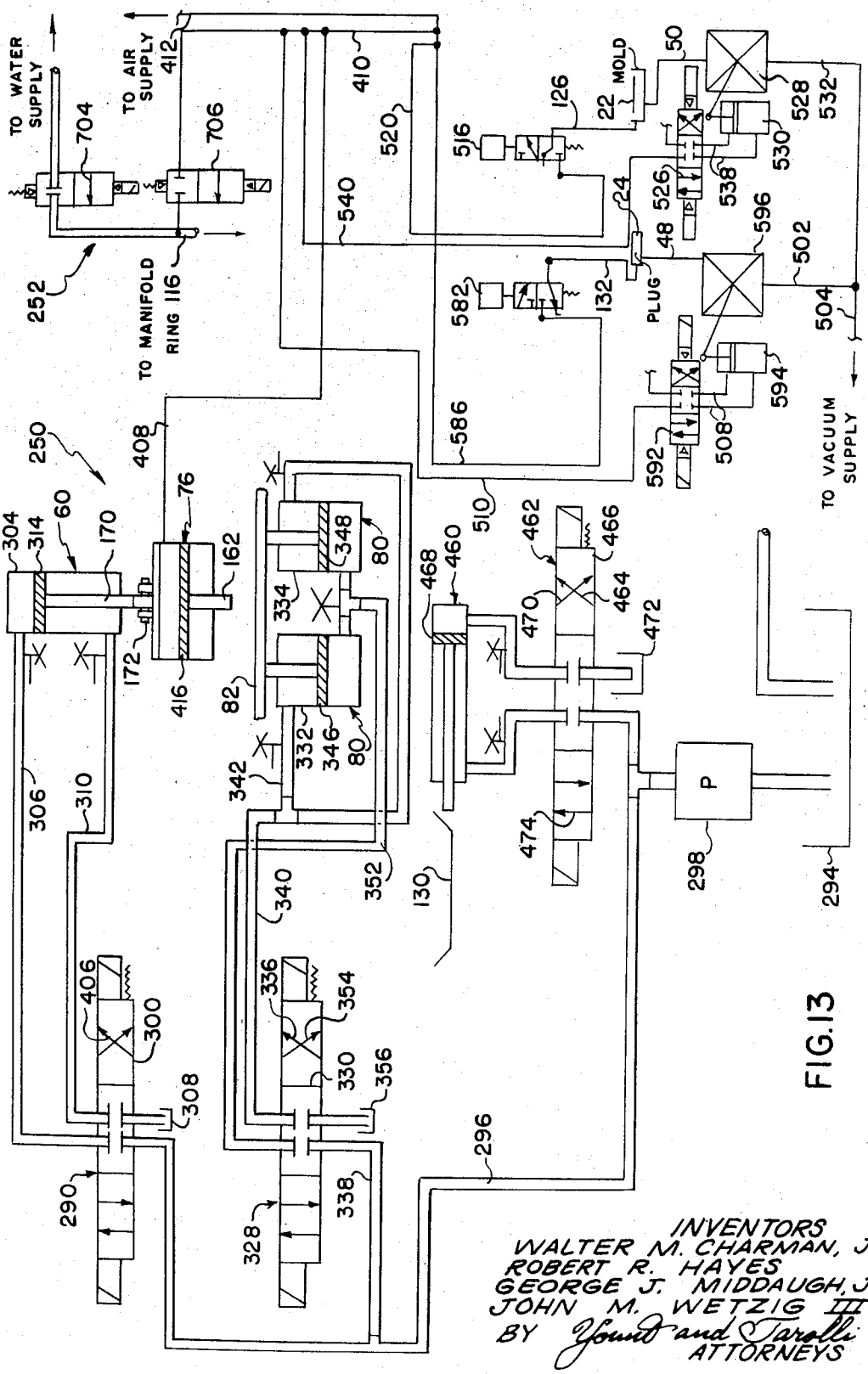


FIG. 13

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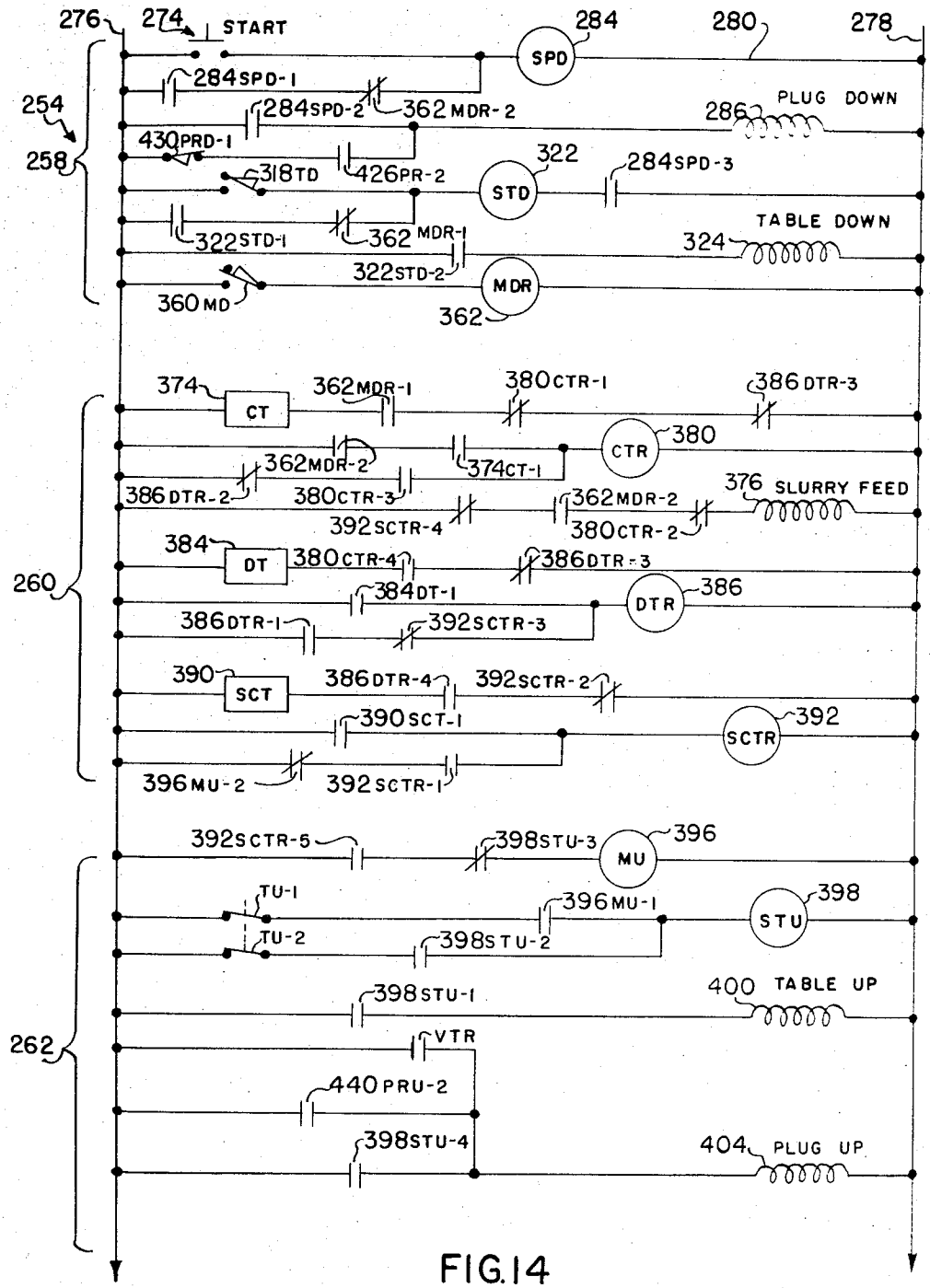


FIG.14

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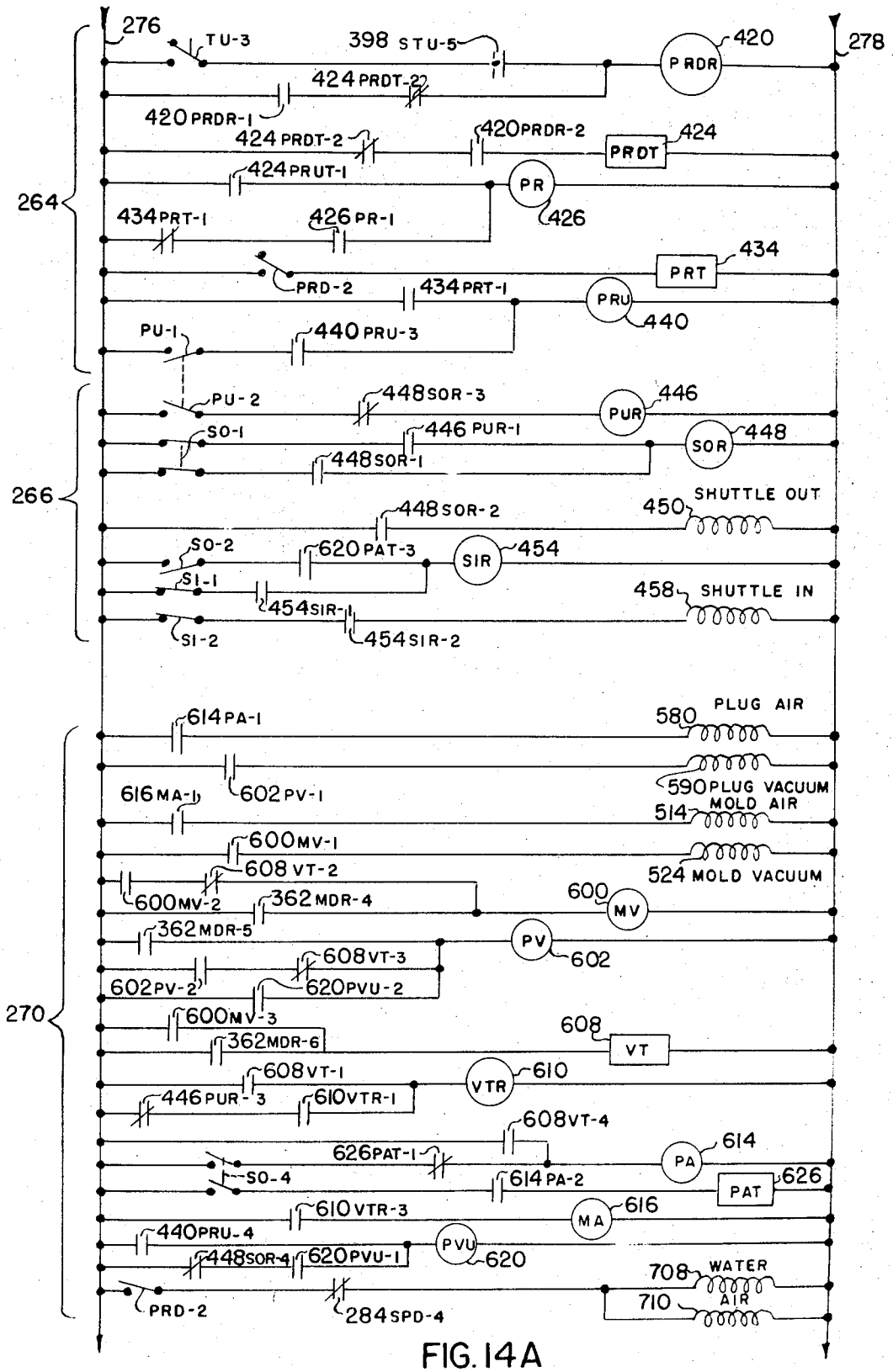

276
TU-3
398 STU-5
420
PRDR
278
424 PRDT-2
420 PRDR-1
424 PRDT-2
420 PRDR-2
PRDT
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424 PRUT-1
PR
426
264
434 PRT-1
426 PR-1
PRT
434
PRD-2
434 PRT-1
PRU
440
PU-1
440 PRU-3
PU-2
448 SOR-3
PUR
446
SO-1
446 PUR-1
SOR
448
448 SOR-1
266
448 SOR-2
450 SHUTTLE OUT
SO-2
620 PAT-3
SIR
454
SI-1
458 SHUTTLE IN
454 SIR-1
SI-2
454 SIR-2
614 PA-1
580 PLUG AIR
590 PLUG VACUUM MOLD AIR
616 MA-1
602 PV-1
514
600 MV-1
608 VT-2
524 MOLD VACUUM
600 MV-2
362 MDR-4
600
MV
362 MDR-5
PV
602
608 VT-3
602 PV-2
620 PVU-2
270
600 MV-3
608
362 MDR-6
VT
608 VT-1
VTR
610
446 PUR-3
610 VTR-1
608 VT-4
626 PAT-1
614
PA
SO-4
614 PA-2
PAT
626
610 VTR-3
MA
616
440 PRU-4
PVU
620
448 SOR-4
620 PVU-1
708 WATER
710 AIR
PRD-2
284 SPD-4

FIG. 14A

METHOD AND APPARATUS FOR FORMING A MEMBER FROM AN EXCESS SLURRY OF REFRACTORY MATERIAL

This invention relates generally to an apparatus for forming a member by depositing material from a slurry of the material in a mold cavity.

Hot tops are commonly used in connection with the casting of ingot steel and frequently include bottom rings to insulate the bottom of a metallic casing from the molten steel. These bottom rings should all have the same density in order to consistently provide desired strength and insulating characteristics. In addition, the bottom rings should have a predetermined axial thickness to enable them to be readily clipped or otherwise secured to the metal casings.

In accordance with the present invention, bottom rings for hot tops are advantageously formed by a molding process. This molding process includes flooding a mold cavity with a slurry of refractory material. Suction is then applied to the slurry in the mold cavity to draw off water from the slurry and deposit refractory material in the mold cavity to form a wet-cake ring. This wet-cake ring has the same configuration as the bottom ring of the hot top and is subsequently dried or cured in a suitable oven to complete the process of making the bottom ring for the hot top.

If bottom rings produced by this molding process are to have the same density so as to provide similar strength and insulating characteristics, the wet-cake rings must all have substantially the same water content. However, the water content of the slurry of refractory material from which the wet-cake rings are formed varies from batch to batch. Therefore, varying amounts of water must be removed from different batches of slurry to form wet-cake rings having the same water content. In addition, the amount of water drawn off from the slurry will vary with the size of the wet-cake ring being formed. Since the refractory material and water forming the slurry tend to separate, the excess slurry from the forming of one wet-cake ring will have a different water content and consistency than the slurry conducted from a mixing tank to form the next ring. Therefore, this excess slurry should be returned to the main batch of slurry before being reused to thereby tend to minimize variations in the water content of the slurry.

Accordingly, it is an object of this invention to provide a new and improved apparatus for forming members from a slurry of refractory material by depositing the refractory material as a wet-cake in a mold cavity wherein the liquid content of the wet-cake is maintained substantially constant during operation of the apparatus with batches of slurry having different liquid contents by controlling the amount of liquid drawn off from the slurry while depositing the refractory material in the mold cavity.

Another object of this invention is to provide a new and improved apparatus for forming a member from a slurry of material by depositing the material in a mold cavity wherein excess slurry from the formation of one member is removed from a work area around the mold cavity and returned to a main tank of slurry before forming the next member to thereby tend to minimize variations in the consistency of the slurry and variations in the density of the member.

Another object of this invention is to provide a new and improved apparatus for forming a member from a slurry of refractory material including a means for flooding a mold cavity with the slurry, suction means for removing liquid from the slurry in the mold cavity to promote the depositing of refractory material in the mold cavity, and selectively adjustable timer means for controlling the length of time for which liquid is removed from the slurry to facilitate controlling the liquid content of the material deposited in the mold cavity.

Another object of this invention is to provide a new and improved apparatus for forming a member from a slurry of refractory material wherein the apparatus includes first and second mold sections which cooperate to form a mold cavity corresponding to the shape of the member, means for forming a trough opening downwardly toward the mold cavity to enable the mold cavity to be flooded with slurry and to hold slurry in excess of the amount required to flood the mold cavity to thereby provide a head of slurry to compensate for any decrease in volume of the slurry in the mold cavity, and means for returning the excess slurry to a source of the slurry where it is mixed with a relatively large quantity of the slurry before being reused.

Another object of this invention is to provide a new and improved apparatus in accordance with the next preceding object wherein the means for forming the trough includes a flexible diaphragm which is movable between a first position extending downwardly toward an opening connecting the mold cavity in fluid communication with the trough and a second position extending downwardly away from the opening to the mold cavity to enable the excess slurry to flow away from the opening toward the means for returning the excess slurry to the source of slurry.

Another object of this invention is to provide a new and improved method of forming a member from a slurry of refractory material including the steps of flooding a mold cavity with slurry from a source of the slurry, drawing liquid from the slurry in the mold cavity and forming a wet-cake of refractory material in the mold cavity by depositing refractory material from the slurry while the liquid is being drawn from the slurry, and returning excess slurry to the source of slurry before reusing it in the formation of another member.

Another object of this invention is to provide a new and improved method of forming a member from a slurry of refractory material, the method including the steps of positioning a flexible diaphragm to form a trough connected in fluid communication with an outwardly opening mold cavity, flowing slurry into the trough to flood the mold cavity and to maintain a head of slurry on the mold cavity, applying suction to the mold cavity to draw off liquid from the slurry in the mold cavity to form a wet-cake of refractory material, flowing slurry from the trough into the mold cavity to compensate for the liquid drawn from the slurry, positioning the diaphragm to enable the slurry in excess of that required to form the member to flow away from the mold cavity, and varying the time for which suction is applied to the slurry in the mold cavity to thereby compensate for variations in the liquid content of the slurry and to facilitate forming members of various sizes.

These and other objects and features of the invention will become more apparent upon a consideration of the following description taken in connection with the accompanying drawings wherein:

FIG. 1 is a partially broken away elevational view of a machine or apparatus constructed in accordance with the present invention and operable to form a member from a slurry of material by depositing the material in a mold cavity;

FIG. 2 is a partially broken away elevational view, taken generally along the line 2—2 of FIG. 1, further illustrating the construction of the apparatus;

FIG. 3 is a plan view, taken generally along the line 3—3 of FIG. 1, further illustrating the construction of the apparatus;

FIG. 4 is a fragmentary sectional view illustrating the relationship between upper and lower sections of the mold in a closed position forming the mold cavity;

FIG. 5 is a schematic illustration of the apparatus of FIG. 1 in an open condition at the beginning of a molding operation;

FIG. 6 is a schematic illustration of the mold sections in a closed position forming a mold cavity;

FIG. 7 is a schematic illustration of the apparatus with the mold sections in a lowered position and a flexible diaphragm forming a trough for holding slurry to flood the mold cavity and maintain a head of slurry on the mold cavity;

FIG. 8 is a schematic illustration of the mold sections in a raised condition in which the flexible diaphragm slopes downwardly and outwardly to enable excess slurry to flow away from the mold sections;

FIG. 9 is a schematic illustration of the forming of an upper surface of the member by moving a press ring downwardly relative to the mold sections and into engagement with an exposed surface of wet-cake material deposited in the mold cavity;

FIG. 10 is a schematic illustration of a mold in an open position with a wet-cake member held on the upper mold section by the application of vacuum to the member;

FIG. 11 is a schematic illustration of depositing of the wet-cake member onto a shuttle assembly;

FIG. 12 is a schematic illustration, similar to FIG. 5, of the apparatus in a position for initiating a second molding operation;

FIG. 13 is a schematic illustration of hydraulic and pneumatic circuitry for effecting operation of the apparatus of FIG. 1; and

FIGS. 14 and 14*a* are schematic illustrations of electrical circuitry for controlling the operation of the apparatus.

The present invention provides an improved molding machine or apparatus 20 for forming a member from a slurry of material. Although the apparatus 20 can be utilized for molding many different kinds of members for use in many different types of environments, it is contemplated that the apparatus will be utilized for the molding of bottom rings for use in hot top assemblies. When bottom rings for hot tops are being formed, the slurry utilized in association with the apparatus 20 advantageously takes the form of a refractory slurry as set forth in U.S. Pat. No. 3,468,368 to Charman et al. However, other slurries could be used if desired.

The molding apparatus 20 (FIGS. 1–3) includes a lower mold section or box 22 and an upper mold section or plug 24 which are movable relative to each other from an open position (FIGS. 1 and 2) to a closed position (FIG. 4). In the closed position the plug 24 and mold section 22 cooperate to form a mold cavity 26. The mold cavity 26 has the configuration of a rectangular ring conforming in shape to the desired shape for a bottom ring of a hot top.

To form a bottom ring, a slurry of refractory material is conducted from a main mixing tank 30 (FIGS. 1 and 2) to a distributing trough or tank 34 by a conduit 36. The slurry is then conducted from the distributing tank 34 through hoses 38 to a trough 42 formed by a flexible diaphragm 44 (FIGS. 3 and 4). The diaphragm 44 slopes inwardly and downwardly (FIG. 4) to direct slurry through an opening 46 into the mold cavity 26. In addition, the trough 42 holds excess slurry to provide a fluid pressure head on the mold cavity 26.

Suction is then applied to the mold sections 22 and 24 by conduits 48 and 50 (FIG. 1) which are connected to a source of low pressure or vacuum. This suction draws water and other liquid from the slurry in the mold cavity 26, through foraminous walls of the mold sections 22 and 24, to thereby promote the depositing of refractory material in the mold cavity in the form of a wet-cake ring. Once the wet-cake ring has been so formed, the diaphragm 44 is movable to an outwardly and downwardly sloping position (FIGS. 1 and 2) to enable the excess slurry held in the trough 42 to flow or run off the diaphragm into a slurry funnel tray assembly or receptacle 54. The excess slurry is drawn from the tray assembly 54 through a conduit 56 (FIG. 2) by a pump 58 and returned to the mixing tank 30. The resulting wet-cake ring is then removed from the apparatus 20 and dried in a suitable oven.

The operation of the molding machine or apparatus 20 is illustrated schematically in FIGS. 5 through 12. The molding machine 20 is shown in an initial condition in FIG. 5 with the mold sections 22 and 24 spaced apart. The upper mold section or plug 24 is lowered by operation of a main piston and cylinder assembly 60 (see FIGS. 1 and 3) to move the upper mold section or plug 24 into engagement with the lower mold section 22 to thereby define a mold cavity 26 (FIG. 4). This vertical movement of the upper mold section or plug 24 is guided by a pair of rods 64 and 66 which extend through sleeves 68 and 70 on a base frame 71 of the apparatus 20 (FIG. 1). The guide rods 64 and 66 are connected to a frame assembly 72 to which the main piston and cylinder assembly 60 is connected by an air spring or secondary piston and cylinder assembly 76.

Once the mold sections 22 and 24 have been closed, they are lowered together by continued operation of the main piston and cylinder assembly 60 and operation of a pair of table piston and cylinder assemblies 80. The piston and cylinder assemblies 80 are operable to raise and lower a table 82 on which the lower mold section 22 is mounted. This downward movement of the two mold sections 22 and 24 moves the flexible diaphragm 44 from the downwardly and outwardly sloping position of FIG. 6 to the downwardly and inwardly sloping position of FIG. 7 to form the trough 42 for holding the slurry 86 of refractory material. The flexible diaphragm 44 is made of a polymeric material,

such as synthetic rubber, and has the configuration of a rectangular ring. Therefore, the trough **42** forms a rectangular moat extending around the cooperating mold sections **22** and **24** to enable the slurry **86** to enter the mold cavity **26** through the opening **46** which is coextensive with the bottom of the trough **42**.

Once the mold cavity has been flooded with the refractory slurry **86**, suction or vacuum is applied to the slurry in the mold cavity **26** through foraminous walls **90** and **94** of the mold sections **22** and **24** (see FIGS. **1** and **4**). This suction draws the water from the slurry in the mold cavity **26** to promote the depositing of refractory material from the slurry **86** in the mold cavity. As the water is withdrawn from the slurry in the mold cavity **26**, excess slurry from the trough **42** enters the mold cavity through opening **46**. Therefore after a short time, the mold cavity **26** is filled with a wet-cake of refractory material deposited from the slurry. This deposited refractory material forms a wet-cake ring **98** (FIG. **7**) having a configuration corresponding to that of the mold cavity **26**.

Once the wet-cake ring **98** has been formed in the mold cavity **26**, the mold sections **22** and **24** are raised by operation of the piston and cylinder assemblies **60** and **80** (see FIG. **8**). Raising the lower mold section **22** moves the diaphragm **44** to an outwardly and downwardly sloping position so that the excess slurry **86** flows over an outer edge portion **102** of the diaphragm **44** and through a space **104** between the outer edge portion of the diaphragm and an outer wall **106** of the slurry funnel tray assembly **54** (see FIGS. **1**, **2** and **8**). The tray assembly or receptacle **54** has an inner wall **110** which is connected with the outer wall **106** by a bottom wall **112**. As is perhaps best seen in FIG. **2**, this bottom wall **112** slopes downwardly toward a receiving area **114** which is connected in fluid communication with the conduit **56** through which slurry is pumped back to the mixing tank **30** where it is mixed with the relatively large body of slurry contained therein before being used to form another ring.

The consistency or water content of the excess slurry retained in the trough **42** is different from that of the slurry when it is initially conducted from the mixing tank **30**. This is because the refractory material in the excess slurry tends to settle out from the water. The refractory material which settles out of the excess slurry tends to gravitate toward the opening **46** to the mold cavity **26** and impedes subsequent filling of the mold cavity. This can result in cavitation in the wet-cake ring **98** and variations in the water content of the slurry in the mold cavity. A water and air spray or wash-down is applied to the area around the plug or upper mold section **24** by a manifold ring **116** when the diaphragm **44** is in the outwardly and downwardly sloping position of FIGS. **1** and **9** to remove any refractory material which may settle out of the excess slurry in the trough **42**. The excess slurry is returned to the tank **30** where it is mixed with a large body of slurry so that the slurry used for making successive wet-cake rings **98** will have substantially the same water content. Therefore, cavitation and variations in the water content of the wet-cake rings **98** tend to be minimized so that successive wet-cake rings have similar strength, density and drying characteristics.

The dried ring **98** will be utilized in a hot top assembly where the ring will have to cooperate with other parts of the hot top assembly (see U.S. Pat. No. 3,468,368). Therefore, it is important that the dimensions of the ring **98** be formed exactly. Since the dimensions of the mold cavity **26** are exactly formed by the foraminous surfaces **90** and **94** of the mold sections **22** and **24**, only the area of the wet-cake ring **98** adjacent to the opening **46** to the mold cavity is free to vary. However, the molding machine **20** includes a press ring **118** which is fixedly connected to the frame **72** (see FIGS. **1** and **2**) and extends around the mold section **24**. The press ring **118** is movable downwardly relative to the mold sections **22** and **24** by operation of the piston and cylinder assembly **60** (see FIGS. **8** and **9**). During this downward movement of the press ring **118**, the air spring or secondary piston and cylinder assembly **76** is forcibly retracted so that the press ring **118** moves axially relative to the upper mold section or plug **24** while the plug and lower mold section **22** remain stationary relative to a floor or other support surface **122** upon which the molding apparatus **20** is supported. In its lowered position, the press ring **118** extends into the opening **46** to engage the refractory material deposited in the mold cavity **26** to exactly form the upper surface of the wet-cake ring **98**.

The fully formed wet-cake ring **98** is then withdrawn from the mold cavity **26** and dried in a suitable oven. To withdrawn the wet-cake ring **98** from the mold cavity **26** air pressure is applied through the conduit **126** (FIG. **10**) to the lower mold section **22** when the mold sections are in the closed position of FIG. **9**. This air pressure is applied against the lower surface of the wet-cake ring **98** through the foraminous surfaces **90** of the lower mold section **22** and enables the wet-cake ring to be readily separated from the lower mold section. The suction or vacuum is maintained on the upper mold section **24** through the conduit **48**. Thus, the wet-cake ring **98** is urged or sucked upwardly against the plug **24** and moves upwardly therewith as the plug is raised from the closed position of FIG. **9** to the open position of FIG. **10** by operation of the piston and cylinder assembly **60**.

A shuttle tray **130** is then moved between the mold sections **22** and **24** to receive the wet-cake ring **98** from the plug **24**. To facilitate depositing of the wet-cake ring on the shuttle tray **130**, air pressure is applied to the plug **24** through a conduit **132** (FIG. **11**). This air pressure is applied against the upper surfaces of the wet cake ring **98** through the foraminous surfaces **94** of the plug **24**. Therefore, the wet-cake ring **98** drops downwardly onto the shuttle tray **130** in the manner illustrated schematically in FIG. **11**. The shuttle tray **130** is then withdrawn from between the mold sections **22** and **24** (FIG. **12**). The wet-cake ring **98** is subsequently transported to an oven where it is dried or cured in a known manner. The density of successive bottom rings produced by the molding machine **20** is substantially the same since the moisture content of the wet-cake rings **98** is substantially constant.

When the plug **24** is moved from the open position of FIG. **5** to the closed position of FIG. **6**, the plug tends to move slightly sidewardly relative to the lower mold section **22** to enable the plug **24** to become aligned with the mold section **22**. To promote this alignment, a plu-

rality of positioning pins 140 project upwardly from the lower mold section 22 (FIG. 1) and engage suitable holes 142 formed in the plug 24 to align the plug 24 and lower mold section 22. The provision of the air spring 76 enables the plug 24 to move sidewardly somewhat relative to the frame 72 to which the press ring 118 is fixedly connected to enable the mold sections 22 and 24 to become properly aligned. The press ring 118 is movable axially relative to the plug 24 between the positions shown in FIGS. 8 and 9. Accordingly, the guide rods 64 and 66 extend through the base frame 71 and are fixedly secured at 146 and 148 to a crosspiece 150 of the frame 72. The plug 24 is fixedly connected by guide rods 154 and 156 with the crosspiece 158 which is connected to a piston rod 162 of the air spring 76. The air spring 76 is pivotally connected at 172 to the piston and cylinder assembly 60 which is fixedly secured to the frame 72 and press ring 118. A universal or ball-type connection 173 is provided between the plug 24 and piston rod 162 of the air spring 76. Therefore, relative movement can occur between the plug 24 and the frame 72 at the joints 172 and 173. In addition, the plug 24 can be moved relative to the frame 72 by moving the piston rod 162 to retract the air spring 76. Retraction of the air spring 76 enables the press ring 118 to move between the raised and lowered positions of FIGS. 8 and 9.

It is contemplated that different size members or hot top rings will be molded with the apparatus 20. Therefore, the plug 24 and lower mold section 22 can be readily replaced with other mold sections to form either larger or smaller mold cavities. To facilitate replacement of the plug 24, the guide rods 154 and 156 are removably fastened at 180 and 182 (see FIGS. 1 and 4) to the crosspiece 158. Similarly, a crosspiece 186 of the frame 72 is detachably fastened at 190 and 192 with projections from the support member 150. Thus, by loosening the connections 180, 182 the plug 24 can be exchanged for another plug. If this other plug has a different outside dimension, the press ring 118 can be removed from the frame 72 by merely loosening the connections 190 and 192 so that a press ring of the proper size can be connected to the support member 150.

Similarly, the lower mold section 22 can be disconnected from the table 82 by quick-release connections 200 which secure the mold section 22 to the table. A mold section of the desired size can then be mounted on the table 82. Of course, it may be necessary to replace the diaphragm 44 with a diaphragm of a different size if the outside dimensions of the lower mold section 22 vary.

The diaphragm 44 is mounted on the slurry funnel tray assembly 54 by means of rods 206 around which the outer end portion 102 of the diaphragm 44 extends. (See FIG. 1). These rods 206 have outwardly projecting end portions 208 which engage brackets 210 at the corners of the slurry funnel tray assembly 54 (see FIG. 3). An inner end portion 214 of the diaphragm 44 is releasably clamped to the lower mold section 22. Thus, the diaphragm 44 can be readily removed for replacement purposes by merely disengaging the rod ends 208 from the brackets 210 and disengaging the diaphragm from the lower mold section 22.

The mold cavity 26 has an innermost end portion 216 (FIG. 4) into which the slurry must be drawn and refractory material deposited if the wet-cake ring 98 is to have the desired configuration. Therefore, the foraminous surface 90 of the lower mold section 22 has an axially extending end wall 218 (FIG. 4) through which suction is applied to the slurry in the mold cavity. In addition, the foraminous surface 94 of the plug 24 extends across the transverse extent of the end portion 216 to enable suction to be applied to the slurry in the end portion 216 from the plug 24. These foraminous surfaces 218 and 94 result in suction being applied to the slurry in the mold cavity 26 in such a manner that slurry is drawn into the end portion 216. Therefore, refractory material is deposited in the end portion 216 and the innermost portion of the wet-cake ring 98 can be readily formed without defects resulting from inadequate deposits of refractory material.

Hydraulic control circuitry 250 for moving the plug 24 and mold 22 between the positions illustrated in FIGS. 5 through FIG. 12 is shown schematically in FIG. 13. Pneumatic control circuitry 252 for controlling the application of high pressure air and suction to the mold cavity 26 is also illustrated in FIG. 13. Electrical control circuitry 254 for controlling the operation of the hydraulic circuitry 250 and pneumatic circuitry 252 is set forth schematically in FIGS. 14 and 14a. It should be noted that the control circuitry of FIGS. 13 and 14 has been shown in a simplified form to avoid prolixity of description. Specifically, well known features such as interlocks, manual overrides, pressure and flow regulators, etc., have been omitted from the control circuitry of FIGS. 13 and 14.

The electrical control circuitry 254 includes six main subcircuits including a subcircuit 258 for controlling the operation of the hydraulic circuitry 250 to move the plug 24 and mold 22 from the open position shown in FIG. 5 to the closed and lowered position shown in FIG. 7. Once the plug 24 and mold 22 have been lowered, a slurry feed control subcircuit 260 is operable to enable slurry to flow into the trough 42 formed by the diaphragm 44 (FIG. 7). Subcircuit 262 is operable thereafter to raise the mold section 22 while maintaining the plug 24 in the closed position (see FIG. 8) so that the excess slurry flows off the diaphragm 44 into the slurry funnel tray assembly or receptacle 54. Following a controlled dewatering or suction time period which varies with different ring sizes and slurry consistencies, the press ring 118 is then moved to the lowered position under the control of subcircuit 264 which, after a predetermined time period, is operable to effect a raising of the press ring and plug 24 to move the mold sections to the open position of FIG. 10. A shuttle control subcircuit 266 is then operable to effect movement of the shuttle tray 130 to a position intermediate the mold sections 22 and 24 and to withdraw the shuttle tray 130 with the wet-cake ring 98 disposed thereon. Finally, subcircuit 270 is operable during the operation of subcircuits 258 through 266 to actuate the pneumatic control circuitry 252 and thereby control the application of high pressure air and suction to the mold cavity.

Assuming that the plug 24 and mold 22 are in the open position of FIG. 5, operation of the molding machine or apparatus 20 is initiated by manually

pressing a start button 274 (FIG. 14). Pressing the start button 274 initiates movement of the plug 24 from the raised position of FIG. 5 toward the lowered position of FIG. 6 by completing a circuit between power lines 276 and 278 through a lead 280 to energize the SPD relay 284. Energization of the SPD relay 284 closes contacts 284SPD-1 to hold the relay energized. In addition, 284SPD-2 contacts are closed to effect energization of a plug-down solenoid 286. Energizing the plug-down solenoid 286 operates the control valve 290 (FIG. 13) from its normal or neutral position in which a flow of hydraulic fluid from a reservoir 294 through conduit 296 under the influence of a pump 298 is blocked. When the plug-down solenoid 286 is energized, valve body 300 of the valve 290 is moved toward the right, as viewed in FIG. 13, to connect the upper end portion of a cylinder 304 of the main piston and cylinder assembly 60 in communication with the pump 298 through conduit 306 and the conduit 296. The lower end portion of the piston and cylinder assembly 60 is exhausted to a reservoir 308 through the valve body 300 and a conduit 310. Thus, high pressure fluid on the upper surface of piston 314 moves the plug 24 downwardly toward the mold 22.

As the plug 24 is lowered, it moves into engagement with the lower mold section 22. At that time a normally open TD limit switch 318 (FIG. 14) in a limit switch assembly 320 (see FIG. 2) is closed to initiate downward movement of the table 82 and mold section 22. It should be noted that the limit switch assembly 320 includes a plurality of spaced switches which are mounted in a fixed relationship with the frame 71 of the molding apparatus 20 and a connector rod 322 which is pivotally connected to the frame 72. Therefore, vertical movement of the plug moves the connector rod 322 relative to the switches of the limit switch assembly 320 to actuate these switches in response to the frame 72 being moved to any one of a plurality of positions under the influence of the main piston and cylinder assembly 60. The limit switches in the assembly 320 have one-way actuators so that they are operated only in response to movement of the connector rod 322 in one direction, either up or down depending upon the condition to which the limit switch is to be responsive.

Closing the normally open TD limit switch 318 energizes the STD relay 322 through normally open contacts 284SPD-3 of the now energized SPD relay 284. The STD relay 322 is maintained energized by closing of normally open 322STD-1 contacts. Closing of normally open 322STD-2 contacts completes the circuit to energize the table-down solenoid 324. Energization of the solenoid 324 operates the table control valve 328 (FIG. 13) by moving a valve body 330 toward the left, as viewed in FIG. 13, to connect the upper ends of cylinders 332 and 334 with high pressure fluid from the pump 298 through a passage 336 in the valve body 330 and fluid conduits 296, 338, 340 and 342. This high pressure fluid causes pistons 346 and 348 to move downwardly and exhaust fluid from the cylinders 332 and 334 through conduit 352 and valve body passage 354 to a reservoir 356.

The plug 24 and mold 22 move downwardly together from the position shown in FIG. 6 to the position shown in FIG. 7. When the plug and mold 24 and 22 reach the lowered or down position of FIG. 7, a normally opened MD limit switch 360 in the limit switch assembly 320 is closed to energize MDR relay 362. Energization of the MDR relay 362 opens normally closed contacts 362MDR-1 and 362MDR-2 to release the holding circuits for the 322STD and 284SPD relays. The de-energization of these relays opens contacts 322STD-2 and 284SPD-2 to de-energize the table-down solenoid 324 and plug-down solenoid 286. The control valves 328 and 290 then return to the normal positions illustrated in FIG. 13 and block fluid flow from the cylinders 332, 334, and 304 to thereby maintain the plug 24 and mold 22 in the position illustrated in FIG. 7.

Once the plug 24 and the mold 22 have been lowered to the position shown in FIG. 7, valve 370 of the slurry feed line 36 is opened by an actuator assembly 372 (FIG. 1) to feed slurry from the main tank 30 to the distributing tank 34. The slurry flows from the distributing tank 34 through the hoses 38 to the trough 42 formed by the diaphragm 44 around the plug 20 and mold 22. The slurry feed control subcircuit 260 (FIG. 14) includes timers which regulate the length of time for which the valve 370 is opened to thereby control the quantity of slurry which flows into the trough 42. Vacuum is then applied to the slurry in the mold chamber 26 to draw off water from the slurry contained therein and promote the deposit of refractory material in a wet-cake in the mold chamber. A supplementary or secondary charge of slurry is provided to maintain the head of slurry in the trough 42 substantially constant even though slurry flows from the trough into the mold cavity to makeup for the water which is drawn off. However, it is contemplated that under certain operating conditions the secondary charge of slurry may be omitted.

When the plug 24 and mold 22 reach the lowered position of FIG. 7 and the MD limit switch 360 is closed to energize the MDR relay 362, a charge timer 374CT is energized by a closing of normally open 362MDR-1 contacts. In addition, a slurry feed solenoid 376 is energized by the closing of normally open 362MDR-2 contacts to operate the valve 370 to the open condition so that slurry flows through the conduit 36 into the distributing trough 34 and from there into the trough 42 formed by the diaphragm 44. At the end of a predetermined time period the charge timer 374 operates or times out to de-energize the slurry feed solenoid 376 and effect a closing of the valve 370. It should be noted that the charge timer 374 is adjustable to enable the period of time for which the valve 370 is opened to be varied to thereby vary the quantity of slurry which is fed into the trough 42. Operation or timing out of the charge timer 374 de-energizes the slurry feed solenoid 376 by closing normally open contacts 374CT-1 to thereby energize CTR relay 380 through the normally open 362MDR-2 contacts of the now energized MDR relay 362. Energization of the CTR relay 380 opens normally closed 380CTR-1 contacts to de-energize the charge timer 374 and opens normally closed 380CTR-2 contacts to de-energize the slurry feed solenoid 376. The CTR relay 380 is then maintained energized over its own normally open contacts 380CTR-3.

A predetermined time period after the initial charge of slurry flows into the trough 42, the slurry feed valve 370 is again opened to enable a secondary or supplemental charge of slurry to flow into the trough 42.

Thus, operation of the CTR relay 380 to energize DT timer 384 which is adjustable to enable the secondary or supplemental charge to be delayed for a desired time period after the initial or primary charge of slurry is provided in the trough 42. At the end of the selected time period, the DT timer 384 operates or times out to close contacts 384DT-1 to effect energization of DTR relay 386 which is then held energized over its own normally open contacts 386DTR-1. Energization of the DTR relay 386 opens normally closed 386DTR-2 contacts in the holding circuit for the CTR relay 380. The resulting de-energization of the CTR relay 380 enables normally closed contacts 380CTR-2 to again close to complete the circuit for energizing a slurry feed valve through the 362MDR-2 contacts of the now energized MDR relay. Normally closed 386DTR-3 contacts in the circuit for energizing the CT timer 374 are opened to prevent reactivation of this timer.

A secondary charge timer 390 controls the duration of time for which the slurry feed valve 376 is opened to enable the secondary charge to flow into the trough 42. The secondary charge timer 390 is selectively adjustable to enable the time period for which the slurry feed valve 376 is opened to be varied to thereby enable the size of the secondary charge of slurry to be adjusted. Thus, energization of the DTR relay 386 to initiate flow of the secondary charge closes normally open contacts 386DTR-4 to energize the SCT timer 390. At the end of the predetermined time period when the SCT timer 390 operates or times out, normally open timer contacts 390SCT-1 are closed to energize the SCTR relay 392 which is then held operated over its own contacts 392SCTR-1. Operation of the SCTR relay 392 opens normally closed contacts 392SCTR-2 to thereby de-energize the SCT timer 390. Normally closed contacts 392SCTR-3 are opened to open the holding circuit for the DTR relay 386. In addition, normally closed contacts 392SCTR-4 are opened to de-energize the slurry feed valve solenoid 376. Thus, operation of the timer 390 effects de-energization of the slurry feed valve solenoid 376 to stop the supplemental charge of slurry to the trough 42.

After the initial and supplemental charges of slurry have been provided in the trough 42, the plug 24 and mold 22 are moved upwardly to the position illustrated in FIG. 8 in which the table 82 is fully raised. To effect this movement, the subcircuit 262 effects actuation of the valves 290 and 328 (see FIG. 13) to operate the piston and cylinder assemblies 60 and 80. Accordingly, operation of the SCTR relay 392, at the end of the supplemental charge, closes normally open contacts 392SCTR-5 to complete a circuit for energizing the MU relay 396. Energization of the MU relay 396 closes normally open contacts 396MU-1 to energize STU relay 398. Energization of the STU relay 398 closes normally open contacts 398STU-1 to energize the table-up solenoid 400. In addition, energization of the STU relay 398 closes contacts 398STU-2 to provide a locking circuit for the relay. The MU396 relay is de-energized by opening of normally closed 398STU-3 contacts to thereby effect de-energization of the SCTR relay 392 by opening 396MU-2 contacts in the holding circuit for the SCTR relay 392. Energization of the STU relay 398 also closes normally open contacts 398STU-4 to energize the plug-up solenoid 404 along with the table-up solenoid 400 to thereby effect upward movement of both the plug 24 and lower mold section 22.

The foregoing energization of the plug-up solenoid 404 effects operation of the valve 290 toward the left as viewed in FIG. 13 to conduct high pressure fluid through a passage 406 in the valve body 300 to the conduit 310 to thereby move the piston 314 upwardly to raise the plug 24. Energization of the table-up solenoid 400 effects operation of the valve 328 toward the right, as viewed in FIG. 13, to connect high pressure fluid through the conduit 352 to the lower side of the cylinders 332 and 334 and to exhaust the upper side of these cylinders through the conduit 340 to thereby effect upward movement of the table 82. This upward movement of the table 82 continues until the mold sections 22 and 24 reach the position shown in FIG. 8 and normally closed limit switches TU-1 and TU-2 (FIG. 14) of the limit switch assembly 320 are opened. Opening these limit switches de-energizes the STU relay 398 so that the table-up solenoid 400 and plug-up solenoid 404 are de-energized by opening of the 398STU-1 and 398STU-4 contacts. De-energizing the table-up solenoid 400 and plug-up solenoid 404 enables the valves 290 and 328 of FIG. 13 to return to their normal positions, under the influence of suitable biasing springs, to block fluid flow to and from the piston and cylinder assemblies 60 and 80. Therefore, the mold 22 and plug 24 are maintained in the position shown in FIG. 8 by the piston and cylinder assemblies 60 and 80.

After the plug 24 and lower mold section 22 have remained in the position shown in FIG. 8 for a predetermined time period during which vacuum is applied to the mold cavity 26, the press ring 118 is lowered by operation of the main piston and cylinder assembly 60 while the piston and cylinder assemblies 80 retain the table in the raised position. It should be noted that this downward movement of the press ring 118 is against the influence of the air spring 76 (FIG. 13) which is continuously connected to a source of air pressure through conduits 408, 410 and 412. The force exerted by the main piston and cylinder assembly 60 is able to overcome the influence of the air spring 76 so that the piston rod 162 forces the piston 416 upwardly to enable the press ring 118 to move downwardly relative to the plug 24 from the position shown in FIG. 8 to the position shown in FIG. 9.

Accordingly, immediately after the plug 24 and mold 22 are raised to the position shown in FIG. 8, PRDR relay 420 is energized by a closing of normally open limit switch contacts TU-3 (FIG. 14*a*) in the limit switch assembly 320. The PRDR relay 420 is then energized through the normally open contacts 398STU-5 of the STU relay 398 (FIG. 14) which is released immediately after the plug 24 and mold 22 have reached the raised position of FIG. 8. The PRDR relay 420 is maintained energized through holding contacts 420PDR-1 to energize PRDT timer 424 over normally open contacts 420PRDR-2 of the energized PRDR relay 420. The PRDT timer 424 delays movement of the press ring 118 from the raised position of FIG. 8 to the lowered position of FIG. 9 for a predetermined time period after the plug 24 and mold 22 reach the position of FIG. 8 and during which vacuum is applied to the mold cavity 26. The timer 424 is selectively adjustable

to enable this time period to be varied to accommodate variations in the length of time for which vacuum is applied to the mold cavity.

At the end of the selected time period, the PRDT timer **424** operates or times out to close normally open contacts **424PRDT-1** to thereby energize PR relay **426** which is then held energized over its own contacts **426PR-1**. In addition, operation of the PRDT timer **424** effects de-energization of the PRDR relay by opening the normally closed contacts **424PRDT-2** in the holding circuit for the PRDR relay **420**. Upon energization of the PR relay **426**, contacts **426PR-2** in the subcircuit **258** are closed to energize the plug-down solenoid **286** and thereby actuate the control valve **290** toward the right as viewed in FIG. **13** to operate the main piston and cylinder assembly **60** and lower the press ring **118** relative to the plug **24** which is retained against downward movement by engagement with the mold **22**.

When the press ring **118** reaches the down or lowered position of FIG. **9**, a one-way normally closed PRD-1 limit switch **430**, in the limit switch assembly **320**, is opened to de-energize the plug-down solenoid **286** so that the valve **290** returns to its normal position in which the flow of fluid to and from the piston and cylinder assembly **60** is blocked by the valve body **300**. Simultaneously with the operation of the PRD-1 limit switch, a normally open PRD-2 limit switch (FIG. **14***a*) is closed to energize a selectively adjustable PRT timer **434**. The PRT timer **434** controls the length of time for which the press ring **118** is in the lowered position. Upon operation or timing out of the PRT timer **434**, normally open contacts **434** PRT-1 close to complete a circuit for energizing PRU relay **440** which initiates upward movement of the press ring **118** by closing normally open contacts **440PRU-2** in the subcircuit **262** (FIG. **14**) to thereby energize the plug-up solenoid **404**. The PRU relay **440** is held up by its own normally open contacts **440PRU-3**. Of course, energization of the plug-up solenoid **404** actuates the valve **290** to the left as viewed in FIG. **13** to retract the piston and cylinder assembly **60** and thereby raise the press ring **118**. It should be noted that operation of the PRT timer **434** also opens normally closed contacts **434PRT-2** in the holding circuit for the PR relay **426**.

The PRU relay **440** and plug-up solenoid **404** are maintained energized until the plug **24** reaches its uppermost position (FIG. **10**). The normally closed PU-1 limit switch (FIG. **14***a*) in the limit switch assembly **320** is then operated to open the holding circuit for the PRU relay **440**. Therefore, normally open contacts **440** PRU-2 are released to de-energize the plug-up solenoid **404** with the plug **24** and mold **22** in the open position of FIG. **10**.

The shuttle tray **130** is then moved to a position between the plug **24** and mold **22**. The wet-cake ring **98** is deposited on the shuttle tray **130** which is then withdrawn to enable the wet-cake ring to be transported to a drying furnace in which it is heated. Accordingly when the plug **24** reaches the upper or raised position of FIG. **10**, the normally opened PU-2 limit switch (FIG. **14***a*) in the limit switch assembly **320** is closed to energize the PUR relay **446**. Energization of the PUR relay **446** closes normally open contacts **446PUR-1** in the shuttle control subcircuit **266** to energize SOR relay **448** which is then held up through its own normally open contacts **448SOR-1**. A shuttle-out solenoid **450** is energized by closing normally opened contacts **448SOR-2** to effect outward movement of the shuttle tray **130** to a position intermediate the raised plug **24** and mold **22**. In addition, normally closed contacts **448SOR-3** are opened to de-energize the PUR relay **446**.

When the shuttle tray **130** reaches its outward position (FIG. **10**), a normally closed shuttle limit switch SO-1 is opened to de-energize the SOR relay **448** and the shuttle-out solenoid **450**. In addition, when the shuttle tray **130** reaches its outward position, a normally open limit switch SO-2 is closed. After operation of the PAT relay **620** in the air and vacuum control subcircuit **670**, the SIR relay **454** is energized and held up by a locking circuit including normally open contacts **454SIR-1**. In addition, normally open contacts **454SIR-2** will be closed to energize a shuttle-in solenoid **458** to retract the shuttle tray **130** with the wet-cake ring **98** thereon. When the shuttle assembly has reached a shuttle-in or retracted position, SI-1 and SI-2 limit switches will be opened to de-energize the SIR relay **454** and the shuttle-in solenoid **458**.

The foregoing movement of the shuttle tray **130** is effected by a shuttle cylinder assembly **460** (see FIG. **13**). Upon energization of the shuttle-out solenoid **450**, a shuttle control valve **462** is moved toward the left, as viewed in FIG. **13**, to conduct high-pressure fluid for the pump **298** through a passage **464** in valve body **466** to move a piston **468** to an extended position or toward the left, as viewed in FIG. **13**. A passage **470** in the valve body connects the opposite end of the piston and cylinder assembly **460** with a reservoir **472**. This movement of the piston **468** moves the shuttle tray **130** to the extended position of FIG. **10**. Similarly, when the shuttle-in solenoid **458** is energized, the valve body **466** is moved to the right of the normal position of FIG. **13** to conduct high-pressure fluid from the pump **298** through a passage **474** to move the piston **468** toward the right and retract the shuttle tray **130**.

During the foregoing operation of the apparatus **20**, the electrical control subcircuit **270** of FIG. **14a** is operable to actuate valves in the pneumatic circuitry **252** of FIG. **13** to apply either suction of vacuum to the plug **24** and mold **22**. Thus, energization of a plug-air solenoid **580** operates a valve **582** in the pneumatic circuitry **252** to connect the plug **24** with a source of air through conduits **132**, **586** and **412**. Energization of a plug vacuum solenoid **590** operates a control valve **592** to operate a piston and cylinder assembly **594** which in turn operates a butterfly valve **596** to connect vacuum to the plug **24** through conduits **48**, **502** and **504**. It should be noted that the valve **592** controls the operation of the butterfly valve **596** by connecting high-pressure air to one of the two sides of the piston and cylinder assemblies through conduits **508**, **510**, **410** and **412**.

Similarly, when a mold-air solenoid **514** is energized, a valve **516** is operated to connect air to the mold **22** through conduits **126**, **520** and **412**. Upon energization of a mold-vacuum solenoid **524**, a valve **526** is operated by a butterfly valve **528** with a piston and cylinder assembly **530** to connect vacuum through conduits **504**, **532** and **50** to mold **22**. The valve **526** controls the operation of the piston cylinder assembly **530** with high

pressure air conducted through the conduits 538, 540, 410 and 412.

When the plug 24 and mold 22 have been moved to the lowered position of FIG. 7 and the trough 42 is being filled with slurry, vacuum is applied to the mold cavity 26 through the foraminous surfaces 90 and 94 of both the plug 24 and mold 22 (see FIG. 4). Thus, when the mold and plug reach the lowered position of FIG. 7, the 360MD limit switch in the subcircuit 258 is closed to energize the MDR relay 362. Energization of the MDR relay 362 closes normally open contacts 362MDR-4 and 362MDR-5 in the air and vacuum control subcircuit 270 to energize MV relay 600 and PV relay 602. Energizing these relays closes normally open contacts 600MV-1 and 602PV-1 to energize the plug-vacuum solenoid 590 and mold-vacuum solenoid 524. Locking contacts 600MV-2 and 602PV-2 are also closed. Whereafter, the valves 592 and 526 (FIG. 13) are actuated to operate the piston and cylinder assemblies 594 and 530 and the butterfly valves 596 and 528 to connect vacuum to the plug 24 and mold 22. In addition, energization of the MDR relay 362 closes contacts 362MDR-6 in the air and vacuum control circuitry 270 to energize selectively adjustable VT timer 608 which controls the length of time for which the suction is applied to the plug 24 and mold 22.

It is contemplated that the water content of the slurry 86 will vary from batch to batch. Therefore, it is necessary for vacuum or suction to be applied to the slurry in the mold cavity 26 for varying lengths of time. Accordingly, the VT timer 608 is adjustable to enable the length of time which vacuum is applied to the mold cavity 26 to be varied.

However, the mold sections 22 and 24 will be raised to the position shown in FIG. 7 before the selected time period elapses. Therefore, the 360MD limit switch will have opened and the MDR relay 363 will have released. Thus, normally open 362MDR-4, 362MDR-5 and 362MDR-6 contacts will be released before the end of the time period for which vacuum is applied to the mold cavity 26. During this time period after the MDR relay 363 is released, the VT timer 608 is energized over contacts 600MV-3 of the now energized MV relay 600. When the selected time period for the application of vacuum has elapsed and the timer 608 operated, contacts 608VT-1 are closed for a short period of time to energize the VTR relay 610 which is then held energized over locking contacts 610VTR-1. Energization of the VT timer 608 opens contacts 608VT-2 to open the holding circuit for the MV relay 600. De-energization of the MV relay 600 de-energizes the mold-vacuum solenoid 524. In addition, operation of the VT timer 608 opens contacts 608VT-3 to de-energize the PV relay 602 and the plug-vacuum solenoid 590.

The foregoing application of suction to the mold cavity 26 has drawn water from the slurry into the plug 24. If the plug 24 is moved to the open condition of FIG. 10 and the wet-cake ring 98 released, by interruption of the suction the water in the plug 24 will also be released. The released water will surge downwardly and tend to erode the wet-cake ring 98. Therefore, the water is discharged from the plug 24 before it is moved to the raised position of FIG. 10.

Accordingly, PA relay 614 is energized by closing of contacts 608VT-4, which are the time delay-release type, to energize the plug-air solenoid 580 by closing of relay contacts 614PA-1. This enables a surge or blast of air to flow into the plug 24 to discharge water drawn from the slurry in the mold cavity 26 from the plug 24. Since the VT timer 608 de-energizes shortly after being operated, this blast of air is relatively short since the time delay contacts 608VT-4 soon return to their normally open condition. Energization of the VTR relay 610 also closes normally open contacts 610VTR-3 to energize MA relay 616. Energization of the MA relay 616 closes normally open contacts 616MA-1 to energize the mold-air solenoid 514 to apply air to the mold section 22. This air frees the wet-cake ring 98 from the surface of the mold section 22. When the PUR relay 446 is energized by movement of the plug 24 to the raised position, 446PUR-3 contacts are opened to release the holding circuit for the VTR relay 610.

Shortly after the application of air to the mold section 22, the PRU relay 440 (see the press ring control circuit 264) is energized to raise the plug 24 upwardly to the position shown in FIG. 10. Energization of the PRU relay 440 closes 440PRU-4 contacts in the control circuitry 270 to energize PVU relay 620 which is locked up over PVU620-1 contacts. In addition, normally open PVU620-2 contacts are closed to energize the PV relay 602 and plug-vacuum solenoid 590 to apply vacuum to the plug 24. This vacuum draws the wet-cake ring 98 against the plug 24 so that the ring is moved upwardly with the plug in the manner illustrated schematically in FIG. 10. Normally closed contacts 448SOR-4 maintain the locking circuit for the PVU relay 620 intact until the shuttle tray 130 reaches the extended or outer position between the mold 22 and plug 24 (FIG. 10). The SO-4 limit switch is then closed to energize the PA relay 614 and close contacts 614PA-1 to energize the plug-air solenoid 580. In addition, normally open contacts 614PA-2 are closed to enable the PAT timer 626 to be energized through the now closed SO-4 limit switch. At the end of a preselected time period during which the wet-cake ring 98 is deposited on the shuttle tray 130, the PAT timer 626 opens normally closed contacts 626PAT-1 to break the holding circuit for the PA relay 614 to thereby de-energize the plug-air solenoid 580. In addition, normally open 626PAT-3 contacts in the shuttle control subcircuit 266 are closed to energize the SIR relay 454 through the now closed SO-2 limit switch. SIR relay 454 is then held energized through its own normally open contacts 454SIR-1 until the shuttle is retracted or moved in and the SI-1 limit switch is opened. As was previously explained, the shuttle-in solenoid 458 is energized upon energization of the SIR relay 454.

When the press ring 118 is lowered (see FIG. 9) slurry which adhered to the outer surfaces of the plug 24 and mold 22 is washed away by a mixture of air and water which is conducted to a manifold ring 116 on the press ring 118 (see FIG. 1). The flow of water to the manifold ring 116 is controlled by a valve 704 in the pneumatic circuit 252 (FIG. 13). The flow of air to the manifold ring 116 is controlled by valve 706 in the pneumatic circuit 252. The valve 704 is operated to an open condition by a water solenoid 708 (see FIG. 14a)

and the valve **706** is operated to an open condition by an air solenoid **710**. The solenoids **708** and **710** are operated when a press ring down limit switch PRD-2 is closed by movement of the press ring **118** from the raised position of FIG. **8** to the lowered position of FIG. **9**. Normally closed contacts **284SPD-4** are provided in the circuit for energizing the solenoids **708** and **710** to prevent the solenoids from being energized when the plug **24** is being initially lowered from the raised position of FIG. **5** to the lowered position of FIG. **7**. By experimentation, it has been determined that the air and water spray from the manifold ring **700** can, if desired, be omitted during operation of the apparatus **20**. In addition it should be noted that the provision of this washdown means is covered by U.S. Pat. No. 3,602,287 to Martin Eversdyk.

From the foregoing description, it can be seen that the molding apparatus **20** is operable to form members or rings **98** from a slurry of refractory material by depositing the refractory material as a wet-cake in a mold cavity **26**. The density of these wet-cake members **98** is maintained substantially constant during operation of the molding machine with batches of slurry having different water contents by controlling the amount of water drawn from the slurry while the slurry is being deposited in the mold cavity **26**. Thus, the vacuum timer **608** is adjustable to vary the length of time for which vacuum or suction is applied to the mold cavity **26**. If a relatively wet slurry is being used, the length of time which the timer **608** is set for will be relatively long. However, if a relatively dry slurry is being used, the timer will be set for a somewhat shorter period. To further promote the formation of wet-cake rings **98** of a constant density, the excess slurry is collected in the receptacle or bay assembly **54** and returned by the pump **58** to the mixing tank **30** before being reused to make a wet-cake ring. This insures that the slurry utilized for making the rings will be of substantially the same consistency.

Having described a specific preferred embodiment of the invention, the following is claimed:

1. Apparatus for forming a member from a slurry of refractory material, said apparatus comprising container means for holding a supply of slurry, a first mold section, a second mold section cooperable with said first mold section to at least partially define a mold cavity corresponding to the shape of the member, means connected with at least one of said mold sections for effecting relative movement between said mold sections, means for forming a trough connected in fluid communication with and opening downwardly toward the mold cavity to direct slurry from said container means into the mold cavity to thereby flood the mold cavity and to hold slurry in excess of the amount required to flood the mold cavity to thereby provide a head of slurry to compensate for any decrease in the volume of slurry in the mold cavity, means for conducting slurry from said container means to said means for forming a trough, and means connected in fluid communication with said container means for returning the excess slurry to said container means to thereby enable the excess slurry to be mixed in the supply of slurry before being reused.

2. Apparatus as set forth in claim **1** wherein said means for forming a trough includes flexible diaphragm means which is movable between a first position extending downwardly toward an opening to the mold cavity to thereby at least partially form a trough for holding the excess slurry and a second position extending downwardly away from the opening to the mold cavity to thereby enable the excess slurry to flow away from the opening toward said means for returning the excess slurry to said container means.

3. Apparatus as set forth in claim **2** wherein said means for returning the excess slurry to said container means includes a receptacle having an outer side disposed outwardly of an outer edge portion of said diaphragm means, said diaphragm means in said second position extending outwardly and downwardly toward said outer side of said receptacle so that the excess slurry will flow off the diaphragm into said receptacle.

4. Apparatus as set forth in claim **1** further including suction means for drawing liquid from the slurry in the mold cavity to promote the formation of the member.

5. Apparatus as set forth in claim **1** further including piston and cylinder means for moving said second mold section relative to said first mold section and means operatively interconnecting said second mold section and said piston and cylinder means for enabling relative movement to occur between said second mold section and said piston and cylinder means.

6. Apparatus as set forth in claim **5** further including a press member fixedly connected to said piston and cylinder means and movable relative to said second mold section between a first position spaced apart from the member being formed in the mold cavity and a second position engaging the member being formed in the mold cavity and spaced a predetermined distance from a mold surface on said first mold section to thereby form a portion of the member in the mold cavity with a thickness corresponding to the predetermined distance.

7. Apparatus as set forth in claim **1** wherein said means for forming a trough is operable between a first condition for holding excess slurry to provide a head of slurry on the mold cavity and a second condition in which the head of slurry is removed from the mold cavity, said apparatus further including means for operating said means for forming a trough between said first and second conditions and selectively adjustable timer means for determining the length of time said means for forming a trough is maintained in said first condition before being operated to said second condition.

8. Apparatus for forming a member from a slurry of material to be deposited to form the member, said apparatus comprising a base, a first mold section operatively connected with said base, a second mold section operatively connected with said base and cooperable with said first mold section to form a mold cavity corresponding to the shape of the member, flexible diaphragm means extending around said first mold section and having an inner edge portion operatively connected to said first mold section, first drive means operatively connected to said base for providing relative movement between said first mold section and said diaphragm means to operate said diaphragm means between a first position in which said diaphragm means at least partially forms a trough connected in fluid com-

munication with the mold cavity and extending around said first mold section and a second position in which said diaphragm means extends downwardly, second drive means operatively connected to said base for providing relative movement between said first and second mold sections to thereby move said first and second mold sections between an open position and a closed position in which said first and second mold sections cooperate to form the mold cavity, means for supplying a quantity of slurry to the trough when said diaphragm means is in the first position and said first and second mold sections are in the closed position to thereby flood the mold cavity with slurry conducted through an opening connecting the mold cavity in fluid communication with the trough and to enable excess slurry to be held in the trough, suction means operatively connected with at least one of said mold sections for drawing liquid from the slurry in the mold cavity and enabling at least a portion of the excess slurry in the trough to flow into the mold cavity to thereby tend to promote the deposition of material from the slurry in the mold cavity to form the member, and control means connected with said first drive means for effecting operation of said first drive means to operate said diaphragm means from said first position to said second position to thereby enable any excess slurry in the trough to flow away from said first mold section after sufficient material has been deposited in the mold cavity to form the member, said control means including selectively adjustable suction timer means for regulating the duration of operation of said suction means to facilitate controlling the depositing of material from the slurry in the mold cavity.

9. Apparatus as set forth in claim **8** further including receptacle means operatively connected with said base and extending around an outer edge portion of said diaphragm means with an outer wall of said receptacle means spaced from the outer edge portion of said diaphragm means whereby any excess slurry in the trough flows over the outer edge portion of said diaphragm means into said receptacle means upon operation of said diaphragm means from said second position to said first position, and pump means connected in fluid communication with said receptacle means for returning slurry from said receptacle means to said means for supplying slurry.

10. Apparatus as set forth in claim **8** wherein said control means further includes selectively adjustable charge timer means for regulating the duration of flow of slurry from said means for supplying slurry into the trough when said diaphragm means is in said first position to thereby facilitate controlling the quantity of slurry which flows into the trough.

11. Apparatus as set forth in claim **10** wherein said control means further includes secondary charge means for enabling a secondary quantity of slurry to flow into the trough from said means for supplying slurry after operation of said charge timer means and the flow of an initial quantity of slurry into the trough to thereby compensate for any slurry which may flow from the trough into the mold cavity to replace liquid drawn from the slurry by operation of said suction means.

12. Apparatus as set forth in claim **11** wherein said control means further includes secondary charge timer means for regulating the duration of flow of slurry into the trough due to operation of said secondary charge means to thereby facilitate controlling the size of the secondary quantity of slurry.

13. Apparatus as set forth in claim **8** further including forming means movable relative to said first mold section between a first position spaced apart from the material deposited in the mold cavity to form the member and a second position engaging the material deposited in the mold cavity and spaced a predetermined distance from a mold surface on said first mold section to thereby form a portion of the member in the mold cavity with a thickness corresponding to the predetermined distance.

14. Apparatus as set forth in claim **13** wherein said control means further includes selectively adjustable timer means for regulating the duration of time for which said forming means is in the second position.

15. Apparatus as set forth in claim **8** wherein said suction means is connected in fluid communication with said second mold section and is operable to urge the member formed in the mold cavity against said second mold section upon movement of said first and second mold sections to the open position in which said second mold section is spaced from and higher than said first mold section whereby the member formed in the mold cavity is maintained in engagement with said second mold section, and shuttle means movable from a position adjacent to one side of said first and second mold sections to a position beneath said second mold section when said first and second mold sections are in the open position, said control means including means for interrupting fluid communication between said suction means and said second mold section when said first and second mold sections are in the open position and said shuttle means is beneath said second mold section to thereby facilitate depositing the member formed in the mold cavity on said shuttle means.

16. Apparatus as set forth in claim **15** further including means for supplying fluid under pressure to said second mold section to apply fluid pressure against the member formed in the mold cavity upon interruption of fluid communication between said suction means and said second mold section to thereby further facilitate depositing the member on said shuttle means.

17. Apparatus as set forth in claim **8** wherein one of said mold sections includes a foraminous mold surface for forming an innermost surface of the member, said suction means being connected in fluid communication with said foraminous mold surface to draw slurry into an innermost end portion of the mold cavity to thereby tend to promote the depositing of material from the slurry at the innermost end portion of the mold cavity.

18. Apparatus as set forth in claim **8** further including means for supplying fluid under pressure, said control means including means for interrupting fluid communication between said suction means and said second mold section after a sufficient amount of material to form the member has been deposited in the mold cavity and for connecting said second mold section in fluid communication with said means for supplying fluid under pressure to discharge liquid drawn from the slurry from said second mold section.

19. A method of forming a member from a slurry of refractory material, said method comprising the steps

of providing a tank containing the slurry, providing a mold cavity remote from said tank, flooding the mold cavity with slurry from said tank of slurry and providing a head of slurry on the mold cavity with a quantity of slurry in excess of that required to flood the mold cavity, drawing liquid from the slurry in the mold cavity and forming a wet-cake of refractory material in the mold cavity by depositing refractory material from the slurry while the liquid is being drawn from the slurry, flowing a portion of the excess quantity of slurry into the mold cavity to compensate for the liquid drawn from the slurry in the mold cavity, and returning the remainder of the excess slurry to said tank of slurry for subsequent reuse in the formation of another member.

20. A method as set forth in claim **19** further including the method step of varying the time for which liquid is drawn from the slurry in the mold cavity to maintain the liquid content of the wet-cake formed in the mold cavity substantially constant even though the liquid content of the slurry varies.

21. A method of forming a member from a slurry of refractory material, said method comprising the steps of providing an outwardly opening mold cavity, positioning a flexible diaphragm to form a trough connected in fluid communication with the mold cavity, flowing slurry into the trough, flooding the mold cavity with slurry from the trough and maintaining a head of slurry on the mold cavity with slurry in the trough, applying suction to the mold cavity to draw off liquid from the slurry in the mold cavity, forming a wet-cake of refractory material in the mold cavity by depositing refractory material from the slurry in the mold cavity while the liquid is being drawn off, flowing slurry from the trough into the mold cavity to compensate for the liquid drawn from the slurry in the mold cavity, positioning the diaphragm to enable slurry in excess of that required to form the member to flow away from the mold cavity, and varying the time for which suction is applied to the slurry in the mold cavity with variations in the liquid content of the slurry to maintain the liquid content of the wet-cake substantially constant even though the liquid content of the slurry varies.

22. A method as set forth in claim **21** further including the method step of forming an outer surface of the wet-cake in the mold cavity by moving a member into engagement with a portion of the wet-cake exposed at the opening to the mold cavity.

23. A method as set forth in claim **21** further including the method steps of collecting the slurry in excess of that required to form the member in a receptacle, and pumping the collected slurry from the receptacle to a tank of slurry to enable the collected slurry to be subsequently reused to form another member.

24. Apparatus for forming a member from a slurry of refractory material, said apparatus comprising a first mold section, a second mold section cooperable with said first mold section to at least partially define a mold cavity corresponding to the shape of the member, means connected with at least one of said mold sections for effecting relative movement between said mold sections, flexible diaphragm means for forming a trough connected in fluid communication with and opening downwardly toward the mold cavity to direct slurry into the mold cavity to thereby flood the mold cavity and to hold slurry in excess of the amount required to flood the mold cavity to thereby provide a head of slurry to compensate for any decrease in the volume of slurry in the mold cavity, suction means operatively connected to at least one of said mold sections for drawing liquid from the slurry in the mold cavity for a predetermined time period, and suction timer means connected with said suction means for selectively adjusting the predetermined time period for which liquid is drawn from the slurry in the mold cavity.

25. Apparatus as set forth in claim **24** further including drive means for moving said first and second mold sections between a first position in which said means for forming a trough is ineffective to direct slurry into the mold cavity and a second position in which said means for forming a trough is effective to direct slurry into the mold cavity, and control means for initiating operation of said suction means and said suction timer means upon flooding of the mold cavity with slurry while said first and second mold sections are in the second position and for effecting operation of said drive means to move said first and second mold sections from the first position to the second position during the predetermined time period during which liquid is drawn from the slurry in the mold cavity.

26. Apparatus as set forth in claim **25** further including selectively adjustable timer means for controlling the period of time for which said first and second mold sections remain in the second position before being moved to the first position under the influence of said drive means.

27. Apparatus for forming a member from a slurry of refractory material, said apparatus comprising a first mold section, a second mold section cooperable with said first mold section to form a mold cavity corresponding to the shape of the member, means connected with at least one of said mold sections for effecting relative movement between said mold sections, flexible diaphragm means for forming a trough connected in fluid communication with and opening downwardly toward the mold cavity to direct slurry into the mold cavity to thereby flood the mold cavity and to hold slurry in excess of the amount required to flood the mold cavity to thereby provide a head of slurry to compensate for any decrease in the volume of slurry in the mold cavity, means connected in fluid communication with the trough for supplying slurry to the trough including valve means operable between a closed condition and an open condition to control a flow of slurry to the trough, and charge timer means connected with said valve means for effecting operation of said valve means to the closed condition after said valve means has been in the open condition for a predetermined time period, said charge timer means being selectively adjustable to vary the predetermined time period to thereby facilitate regulating the amount of slurry supplied to the trough.

28. Apparatus as set forth in claim **27** wherein said charge timer means includes primary timer means for effecting operation of said valve means from the open condition to the closed condition after a first predetermined period to thereby regulate the amount of slurry supplied to the trough in a primary charge of slurry and secondary timer means for effecting operation of said valve means from the closed condition to the open condition after the primary charge of slurry is supplied to

the trough to thereby supply a secondary charge of slurry to the trough, said secondary timer means being operable to effect operation of said valve means from the open condition to the closed condition after a predetermined time period to thereby regulate the amount of slurry supplied to the trough in a secondary charge of slurry.

29. Apparatus as set forth in claim 28 further including suction means operatively connected to at least one of said mold sections for drawing liquid from the slurry in the mold cavity for a predetermined time period during which the primary and secondary charges of slurry are supplied to the trough, and suction timer means for selectively adjusting the predetermined time period for which liquid is drawn from the slurry in the mold cavity by said suction means.

30. Apparatus as set forth in claim 27 further including suction means operatively connected to at least one of said mold sections for drawing liquid from the slurry in the mold cavity for a predetermined time period, and suction timer means for selectively adjusting the predetermined time period during which liquid is drawn from the slurry in the mold cavity.

31. Apparatus as set forth in claim 27 further including drive means for moving said first and second mold sections between a first position in which said means for forming a trough is ineffective to direct slurry into the mold cavity and a second position in which said means for forming a trough is effective to direct slurry into the mold cavity, and control means for effecting operation of said valve means to the open condition and for initiating operation of said charge timer means upon movement of said first and second mold sections to the second position.

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