Sept. 18, 1956 R. DOAT 2,763,041

AUTOMATIC CASTING APPARATUS

Filed Jan. 27, 1954 5 Sheets-Sheet 1

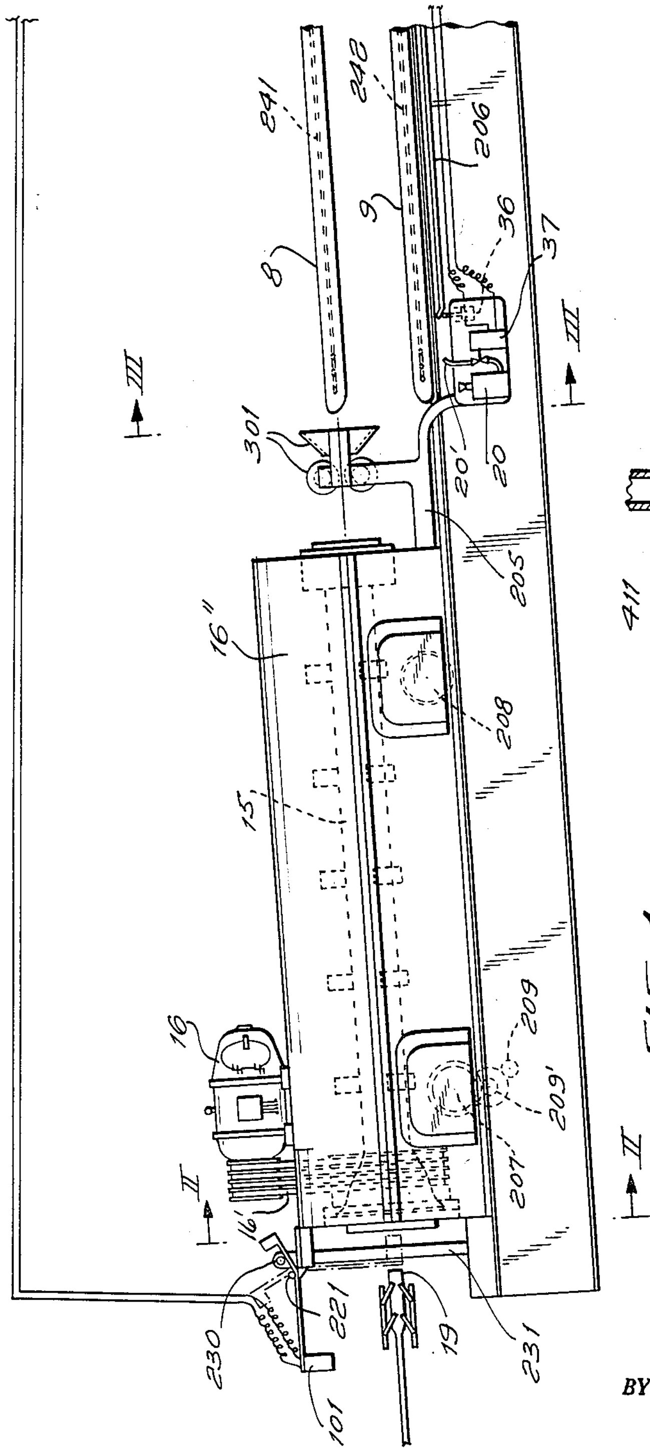

FIG. 1a.

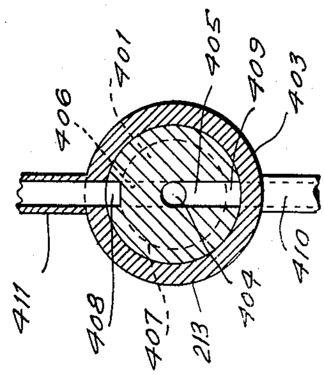

FIG. 6.

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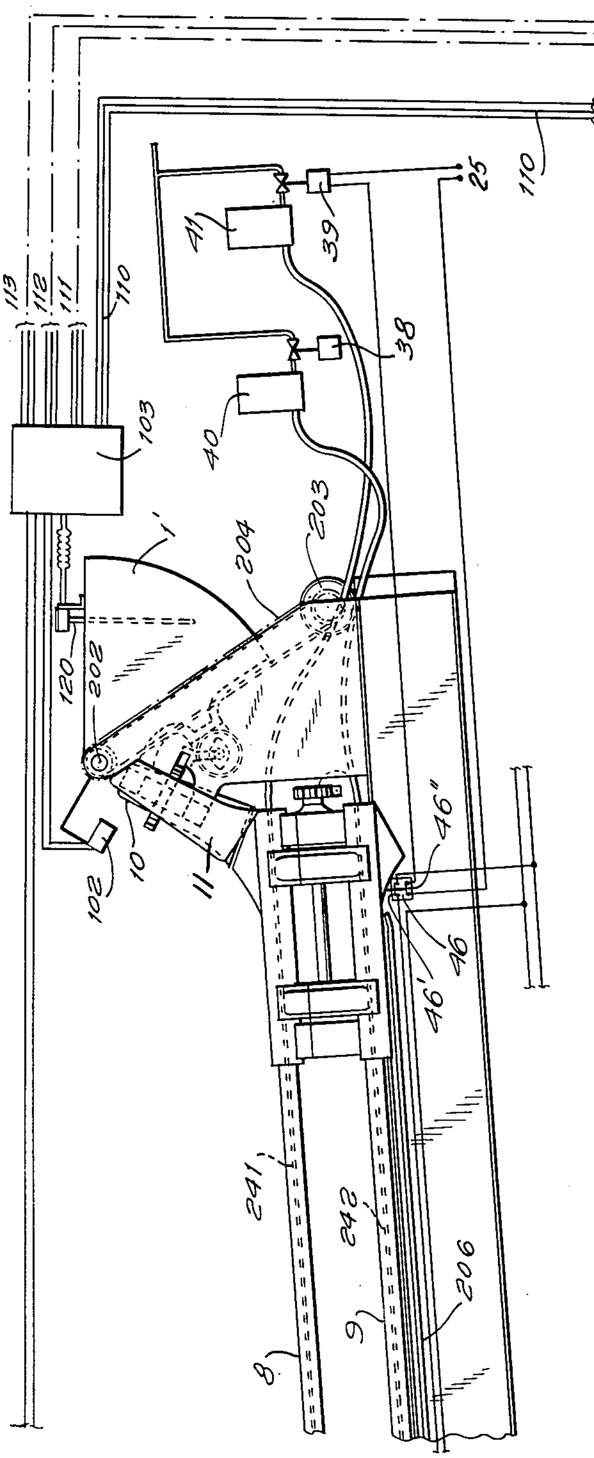

FIG. 1b.

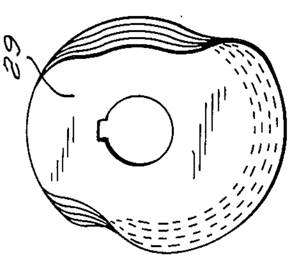

FIG. 4a.

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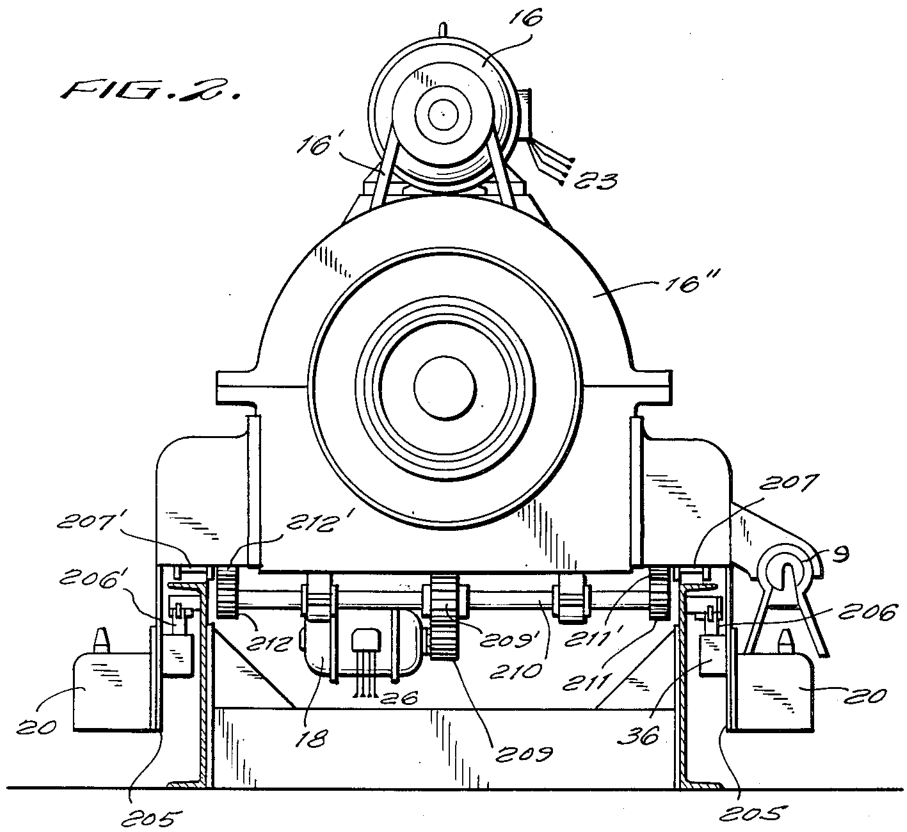
Sept. 18, 1956 R. DOAT 2,763,041

AUTOMATIC CASTING APPARATUS

Filed Jan. 27, 1954 5 Sheets-Sheet 3

FIG. 2.



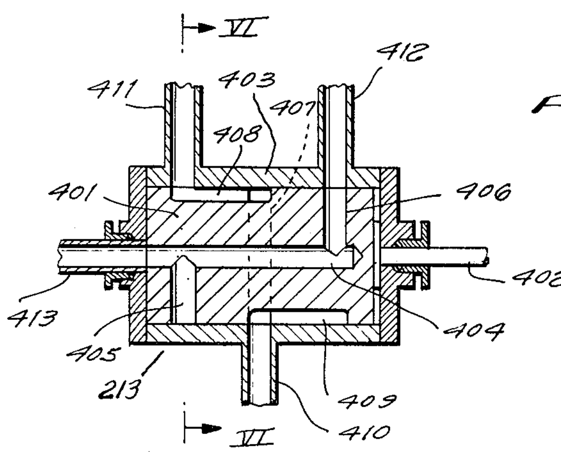


FIG. 5.

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Sept. 18, 1956 R. DOAT 2,763,041

AUTOMATIC CASTING APPARATUS

Filed Jan. 27, 1954 5 Sheets-Sheet 4

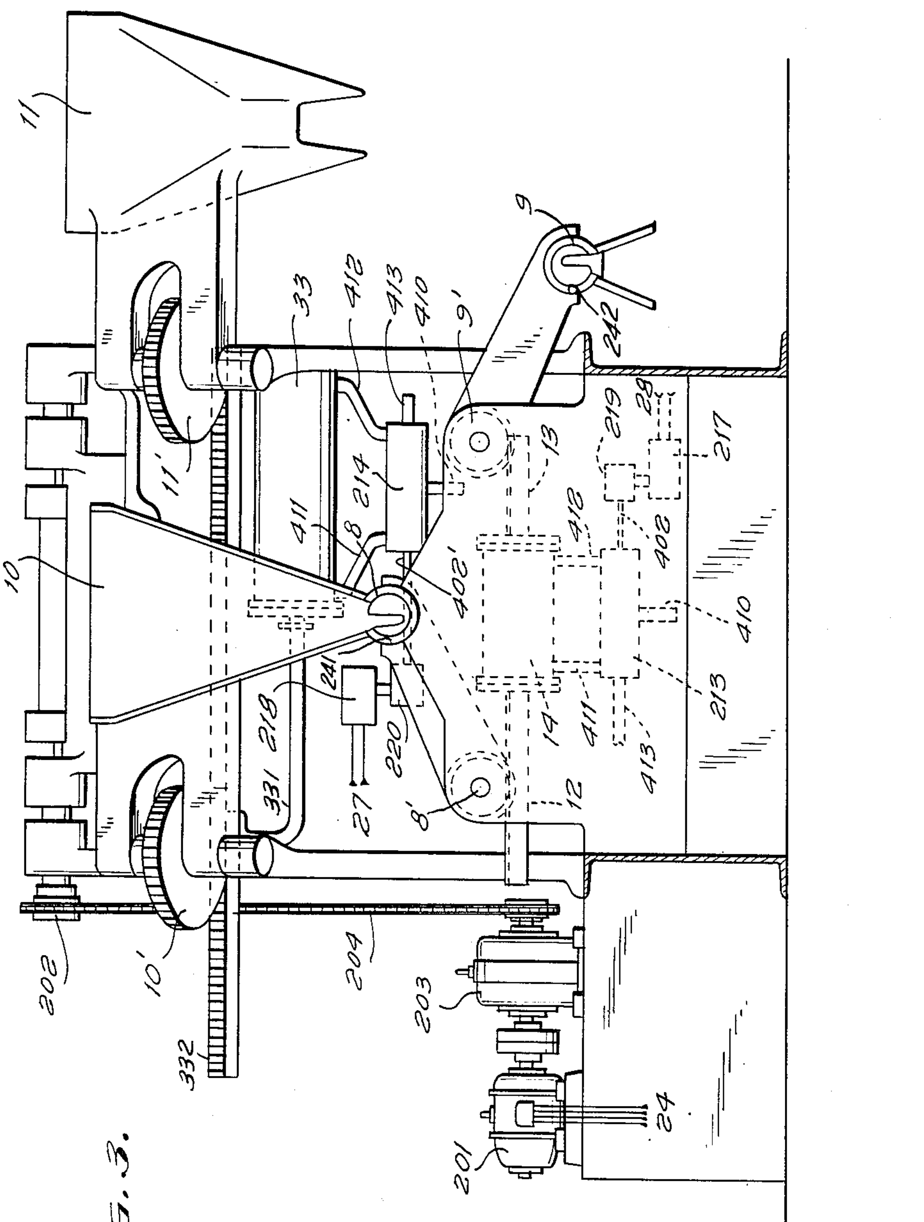

FIG. 3.

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Sept. 18, 1956 R. DOAT 2,763,041

AUTOMATIC CASTING APPARATUS

Filed Jan. 27, 1954 5 Sheets-Sheet 5

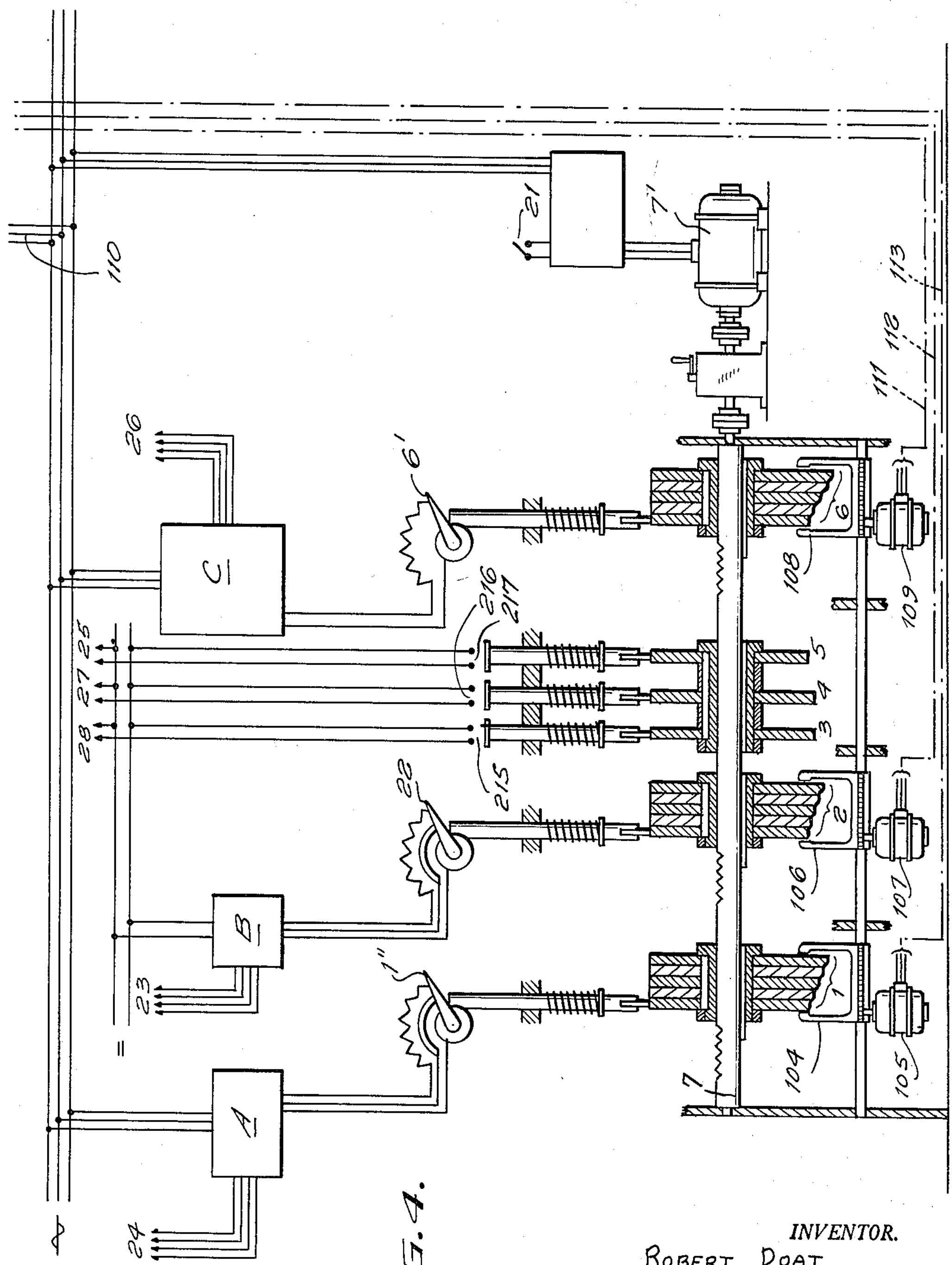

FIG. 4.

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1

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AUTOMATIC CASTING APPARATUS

Robert Doat, Liege, Belgium

Application January 27, 1954, Serial No. 406,450

Claims priority, application Belgium August 12, 1949

19 Claims. (Cl. 22—65)

The present invention relates to automatic casting machines which are used to form an object of a desired shape from a liquid material which solidifies upon cooling. For example, the present invention is applicable to machines for automatically casting seamless pipe.

This application is a continuation-in-part of copending U. S. application Serial No. 178,593, filed August 10, 1950, and entitled "Automatic Centrifugal Casting Machine," now abandoned.

Although automatic casting machines are known, they have serious defects which have not been overcome up to the present time. Thus, it is impossible with the known machines to produce truly uniform products. The reason for this is that the known automatic machines can only be operated in such a way that the parts thereof follow a predetermined, fixed, unchanging cycle. Since the material handled by the machine does not have fixed, unchanging properties, lack of uniformity in the products necessarily results. That is, the unchanging cycle of the machine parts cannot produce uniform products if, for example, the temperature and/or viscosity of the liquid material changes, and it is impossible to avoid such changes. For example, while the liquid material dwells in the ladle it is necessarily cooling. This is but one example of unavoidable variables which cannot be taken account of by known automatic machines. It should be noted that the problem cannot be completely solved by an attendant who makes adjustments because then the machine is not fully automatic, and furthermore such adjustments include errors necessarily inherent in human judgment. Also, adjustments of this type are necessarily temporary.

One of the objects of the present invention is to overcome the above drawbacks by providing an automatic casting machine of the above type with a means for adjusting the cycle of operations performed by the parts of the machine.

A further object of the present invention is to provide an automatic casting machine with a means for automatically adjusting the operations performed by the parts of the machine.

Another object of the present invention is to automatically adjust the operation of the machine parts to changes in the properties of the material handled by the machine parts so that uniformity of the products produced by the machine is assured.

An additional object of the present invention is to automatically adjust the operation of the machine parts to changes in the viscosity and/or temperature of the material handled by the machine so that changes in these properties will not alter the uniformity of the products produced by the machine.

Still another object of the present invention is to provide an automatic casting machine with control elements which are capable of being automatically moved to adjust the operation of the machine to changes in the properties of the material handled by the machine.

A still further object of the present invention is to

2

provide an automatic casting machine which is capable of continuously repeating cycles of operation while automatically adjusting the operation of the parts to variations in the properties of the material handled by the machine.

A still additional object of the present invention is to provide an apparatus capable of accomplishing all of the above objects and made up of simple and ruggedly constructed parts which are relatively inexpensive to manufacture and which will give reliable service for a long period of time.

With the above objects in view, the present invention mainly consists of an automatic casting machine for forming an object of desired shape from a liquid material which solidifies upon cooling, this machine including a plurality of machine elements which constitute a casting machine proper. An automatic operating means is operatively connected to the machine elements for automatically, continuously and cyclically operating the same at predetermined speeds, for predetermined durations, and in a predetermined sequence during each cycle. A detecting means is mounted on the machine for detecting variations in the properties of the liquid material during handling thereof by the machine elements. An adjusting means is operatively connected to the operating means for adjusting the latter to regulate the speeds and duration of operation of the parts, and an actuating means connects the detecting means to the adjusting means for automatically actuating the latter to compensate for material variations detected by the detecting means, whereby a uniform object is automatically produced during each cycle irrespective of variations in the properties of the liquid material during handling thereof by the machine.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which:

Figs. 1*a* and 1*b* are continuations of each other and show a side, elevational diagrammatic view of a casting machine adapted to be used with the present invention;

Fig. 2 is a sectional view of the machine taken along line II—II of Fig. 1*a* in the direction of the arrows;

Fig. 3 is a sectional view of the machine taken along line III—III of Fig. 1*a* in the direction of the arrows;

Fig. 4 is a partly sectional, partly schematic elevational view of a control apparatus electrically connected to the machine of Figs. 1*a* and 1*b*;

Fig. 4*a* is an end view of one of the cams of Fig. 4;

Fig. 5 is a fragmentary, partly sectional view of a valve apparatus shown in Fig. 3; and

Fig. 6 is a sectional view taken along line VI—VI of Fig. 5 in the direction of the arrows.

Referring now to the drawings, and more particularly to Figs. 1*a* and 1*b*, it will be seen that the casting machine of the invention includes a base at the left end of which, as viewed in Fig. 1*a*, is located a carriage **16″** which turnably carries the elongated hollow mold **15** which is adapted to centrifugally cast seamless pipe, although it is to be understood that this is but an example of the invention which is in fact applicable to machines capable of forming any liquid material into an object of desired shape upon solidification of the liquid. A motor **16** is mounted on the carriage **16″** and rotates the mold **15** about its axis through the belts **16′** and pulleys cooperating with the latter.

A motor **18** (Fig. 2) is connected to the underside of carriage **16″** and drives a pinion **209** which meshes with a gear **209′** fixed to the shaft **210** which is rotatably supported at the underside of the carriage **16″**. A pair of gears **211** and **212** are also fixed to the shaft **210** and respectively mesh with gears **211′** and **212′** which are respectively connected to the wheels **207** and **207′** which turnably support the carriage **16″** on the inclined base. As is evident from Fig. 1*a*, a pair of additional wheels **208** and **208′** support the carriage **16″** for movement along the base. Thus, when motor **18** is operating, a drive will be transmitted to the wheels **207** and **207′** for driving the carriage **16″** along the base.

Liquid material is supplied to the interior of mold **15** through the channels **8** and **9** which are alternately located in an operating position, in a manner described below, so that while one channel is being used the other channel is cooling and is being made ready for use. In Figs. 1*a*, 1*b* and 3 the channel **8** is shown in the operating position, while the channel **9** is shown in its rest position.

A frame **205** is fixed to the front end of the carriage **16″** and extends forwardly therefrom along the opposite outer sides of the base, as is evident from Fig. 2. The uppermost portion of frame **205** carries the roller and guide assembly **301** for guiding the channels **8** and **9** to guarantee that the latter are located along the central axis of mold **15** when the latter together with carriage **16″** is located to the right of the position shown in Fig. 1*a* with one of the channels **8** or **9** extending into the interior of the mold **15**.

On each side of the base, the frame **205** carries a reservoir **20** which holds a cooling material for cooling the channels. Thus, the right hand reservoir **20**, as viewed in Fig. 2, is adapted to cool the channel **9**, when the latter is in its rest position, as shown in Figs. 1*a*–3, and the left hand reservoir **20**, as viewed in Fig. 2, is adapted to cool the channel **8**, when the latter is in its rest position. Each reservoir **20** communicates with a flexible conduit **20′** which is adapted to supply a fluid under pressure to the reservoir **20** for forcing the cooling material therefrom. An electrically operable valve **37** is connected into the conduit **20′** for controlling the flow of fluid under pressure to the reservoir **20**, and the circuit of electric valve **37** is adapted to be closed and opened by a switch **36**. The switch **36** on the right hand side of the machine, as viewed in Fig. 2, cooperates with a rail **206** fixed to the outer right side of the base, while the switch **36** on the left side of the machine, as viewed in Fig. 2, cooperates with a rail **206′** identical with rail **206** and fixed to the opposite side of the base. As is evident from Fig. 1*a*, when the carriage **16″** is in its leftmost position, as viewed in Fig. 1*a*, the switch **36** is located opposite the upwardly bent left end portion of rail **206** (or **206′**), and therefore the switch **36** is open at this time. However, upon movement of carriage **16″** to the right, as viewed in Fig. 1, both switches **36** will engage the rails **206** and **206′**, respectively, and will therefore be closed.

It is necessary therefore to make certain that the circuit to only one of the valves **37** is completed, since, when channel **8** is in its operating position as shown in the drawing the left reservoir **20**, as viewed in Fig. 2, should not be operated. Therefore, a switch assembly **46** is mounted on each side of the base to be engaged and closed by one of the channels **8** or **9** when it is in its rest position. It will be seen from Fig. 1*b* that the upper switch **46′** of switch assembly **46** is connected in series with switch **36** so that valve **37** will only be energized when switch **46′** is closed. Thus, with the position of the parts shown in Figs. 1–3 the valve **37** located adjacent channel **9** will only be energized since the switch assembly **46** on the left side of the machine, as viewed in Figs. 2 and 3, is necessarily open because the channel **8** is in its operative position. As will be pointed out below, when the channel **8** is moved down to its rest position at the left side of the machine, as viewed in Figs. 2 and 3, the channel **9** will be located in the operating position previously occupied by channel **8**, and the channel **8** will close the switch assembly **46** on the left side of the machine, as viewed in Figs. 2 and 3, while the switch assembly **46** on the opposite side of the machine will remain open.

The liquid material which is handled by the machine is supplied from a structure (not shown) to the ladle **1′** which is tiltably carried by the base of the machine, and when the ladle **1′** is tilted in a counterclockwise direction, as viewed in Fig. 1*b*, the liquid material therein flows into a channel **10** which feeds into the channel **8**, or into a channel **11** which feeds into the channel **9**. Channels **8** and **10** moving together to and from the operating position in which these channels are located when the parts are in the position shown in Figs. 1*b* and 3, and the channels **11** and **9** also move together to and from the operating position occupied by channels **10** and **8** when the parts are in the position shown in the drawings.

Means are provided to alternately move channels **10** and **8**, on the one hand, and **11** and **9**, on the other hand, to and from this operating position. This latter moving means takes the form of a piston and cylinder arrangement **14** which cooperates with channels **8** and **9** and a piston and cylinder arrangement **33** which cooperates with channels **10** and **11**. As is evident from Fig. 3, the piston of the arrangement **14** has opposite extensions extending slidably through the end walls of the cylinder, the latter being sealed to prevent the fluid from escaping therefrom. These extensions are respectively integral with racks **12** and **13** which respectively mesh with pinions **8′** and **9′** fixed to shafts, respectively, which are turnably carried on the base of the machine, these shafts in turn being respectively fixed to channels **8** and **9**. Thus, upon movement of the piston and the racks **12** and **13** therewith to the right, as viewed in Fig. 3, the gears **8′** and **9′** will be turned in a counterclockwise direction, as viewed in Fig. 3, to move the channel **8** from the operating position and to simultaneously move the channel **9** to the operating position. Also, when the racks **12** and **13** move to the left, as viewed in Fig. 3, to the position shown in Fig. 3, the gears **8′** and **9′** will be turned in a clockwise direction, as viewed in Fig. 3, to move the channel **9** from the operating position and simultaneously move channel **8** to the operating position. Conduits **411** and **412** communicate with the interior of the cylinder at opposite sides of the piston, and fluid is fed to the conduits **411** and **412** by a valve **213**, the details of which are shown in Figs. 5 and 6.

Referring to Figs. 5 and 6, it will be seen that the valve **213** includes a cylindrical casing **403** which communicates at one end with a conduit **413** which leads fluid at low pressure back to a tank or the like, a pump communicating with this tank and feeding fluid under pressure to the conduit **410** which communicates with the interior of cylinder **403** at a central portion thereof. A cylindrical valve member **401** is turnably mounted in the casing **403** and is formed with an axial bore **404** in constant communication with the discharge conduit **413**. The bore **404** also communicates with radially extending bores **405** and **406**, the bore **406** communicating with the conduit **412** in the position of the valve shown in Fig. 5. The bores **405** and **406** are displaced by 180° from each other. The cylindrical valve member **401** is also formed with a central peripheral groove **407** communicating with axially extending grooves **408** and **409**, these latter grooves **408** and **409** respectively being angularly aligned with the bores **406** and **405**. Thus, the groove **408** communicates with conduit **411** when bore **406** communicates with conduit **412**, as shown in Fig. 5, and at the same time axial groove **409** communicates with conduit **410** to receive fluid under pressure therefrom. Thus, with the valve in the position shown in Figs. 5 and 6, the fluid under pressure flows along conduit **411** into the left end of the cylinder of the arrangement **14**, and fluid simultaneously discharges through conduit **412** to conduit **413**, so that this position of the valve causes racks **12** and **13** to be displaced to the right, as viewed in Fig. 3, which will result in movement of channel **8** from its operating position and channel **9** to its operating position. If the valve member **401** is turned through 90°, the flow of pressure fluid to and from the arrangement **14** is cut off, whereas if the valve **401** is turned through an additional 90°, bore **405** communicates with conduit **411** and groove **409** communicates with conduit **412** to move racks **12** and **13** to the left, to the position shown in Fig. 3. The valve member **401** is fixed to an end of a shaft **402** which is turned by a motor **217** through the speed-reducing transmission means **219** (Fig. 3).

The piston and cylinder arrangement **33** operates in the same way as arrangement **14**. The piston of arrangement **33** is connected to a rod **331** which is fixed to a rack **332** which meshes with gears **10'** and **11'** respectively fixed to shafts which also are supoprted for rotation on the base of the machine. These latter shafts are in turn fixed to the channels **10** and **11**, in the manner most clearly shown in Fig. 3. Thus, upon movement of the piston of the arrangement **33** to the left, as viewed in Fig. 3, channel **10** will be moved from the operating position shown in Fig. 3 and the channel **11** will be moved to this operating position, whereas when this piston moves to the right, as viewed in Fig. 3, channel **10** will be moved to the operating position and channel **11** will be moved from this operating position. The operations of the piston and cylinder arrangements **14** and **33** are synchronized so that channels **8** and **10** move together and so that channels **9** and **11** move together in the manner described above. The piston and cylinder arrangement **33** is controlled by a valve **214** identical with valve **213** described above. The conduits **410—413** cooperate with valve **214** and arrangement **33** in the same way that the conduits having these same reference characters cooperate with valve **213** and arrangement **14**. The valve member of valve **214** is also turned by a shaft **402'**, this latter shaft **402** being driven by the motor **218** through the speed-reducing transmission **220**.

The ladle **1'** is fixed to the horizontal shaft **202** which is turnably carried on the base, and a sprocket wheel is fixed to shaft **202** and cooperates with a sprocket chain **204** which is driven by the motor **201** through the speed-reducing transmission **203** (Fig. 3).

At the left end of Fig. 1*a* is shown an extracting bar **19** which is adapted to be moved into and out of the left end of mold **15** for removing therefrom a finished seamless pipe. The structure for moving and operating the bar **19** forms no part of the present invention.

A tube **241** is fixed to the outer surface of channel **8**, and a tube **242** is fixed to the outer surface of channel **9**, these tubes being perforated at their left end portions, as viewed in Fig. 1*a*, and being adapted to distribute a powder against the inner face of the mold **15** just prior to contact of the liquid material with the inner face of the mold. The tubes **241** and **242** move together with the channels **8** and **9**, respectively, and are respectively connected to and in communication with flexible tubes which respectively communicate with containers **41** and **40** which hold the powder which is distributed against the inner surface of the mold **15**. As is evident from the right hand portion of Fig. 1*b*, fluid pressure lines communicate with the containers **40** and **41**, and electrically operated valves **38** and **39** are respectively located in the fluid pressure lines leading to containers **40** and **41**, respectively. As is evident from Fig. 1, the switch assembly **46** which cooperates with channel **9** includes a switch **46''** which is closed when channel **9** is in its rest position for completing a part of an electrical circuit to the valve **39** so that when the remainder of this circuit is closed, in a manner described below, valve **39** will be opened so that powder will be moved along the tube **241** to be distributed to the inner face of the mold **15**. In the same way, the switch assembly **46** on the opposite side of the base cooperates with channel **8**, when the latter is in its rest position, to close part of a circuit to the valve **38** which, when energized, admits fluid under pressure to container **40** so that powder will be distributed from tube **242** to the inner face of the mold when channel **9** is in its operating position. This powder may be Fe-Si powder, as is well known in the art.

All of the above-described structure constitutes a casting machine proper. The present invention includes a control apparatus for automatically operating the parts of the casting machine proper in a predetermined sequence, for predetermined durations and at predetermined speeds, during each of a number of cycles which may be indefinitely and automatically repeated by the machine. This structure for thus automatically operating the parts of the casting machine proper is shown in Fig. 4. Referring to Fig. 4, it will be seen that the control apparatus includes a support on which the shaft **7** is turnably mounted, this shaft **7** being driven by the motor **7'** through a governor of any known construction which guarantees that the shaft **7** will rotate at a constant speed which may be set by adjustment of the governor, as is well known. The apparatus may be stopped and started by opening and closing, respectively, the switch **21** shown in Fig. 4. The shaft **7** carries cams **1—6** which are mounted on the shaft **7** for rotation therewith, these cams respectively cooperating with six cam followers mounted for reciprocating movement on the support of the control apparatus and being urged by coil springs toward the cams **1—6**, respectively, as is evident from Fig. 4. The followers which cooperate with cams **1**, **2** and **6** are respectively operatively connected to variable resistors **1''**, **22**, and **6'**.

The variable resistor or potentiometer **1''** is electrically connected to the lines **24** leading to the motor **201** which controls the tilting of the ladle **1'**. The motor **201** is an induction motor, and two of the leads energize the field or stator windings thereof while the other two leads energize the rotor or armature windings thereof. Although the potentiometer **1''** may by itself regulate the speed and direction of rotation of the motor **201**, in the example illustrated the potentiometer **1''** is connected to an electronic installation A which includes such elements as thyratrons the voltage of which is controlled by the potentiometer **1''**, this voltage being applied to the grids of the thyratrons which thus proportionally vary the anode currents of the thyratrons. Through the medium of electro-magnetic relays, these variable anode currents regulate the value and direction of current induced in the motor **201** so that the speed and direction of rotation of the latter is controlled by the cam **1**.

In the same way the cam **2** controls the variable resistor **22** which through the electronic installation B, similar to the electronic installation A, controls the speed of rotation of motor **16**, as well as the stopping and starting thereof through the electrically conductive leads **23**, the motor **16** being similar to the motor **201**. The variable resistor **6'** is controlled by the cam **6** to operate the motor **18** through the electrically conductive leads **26** and the electronic installation C, which, in the same way as was described above in connection with motor **201**, control the speed and direction of rotation of the motor **18**.

The follower which cooperates with cam **3** opens and closes the switch **215** which through the electrically conductive leads **28** stops and starts the motor **217** to turn the valve member of valve **213** periodically through 90° so that the flow of fluid pressure to and from the cylinder and piston arrangement **14** is regulated to move the channels **8** and **9** in the manner described above. In the same way the follower which cooperates with cam **4** closes and opens a switch **216** which through the electrically conductive leads **27** stops and starts the motor **218** for operating valve **214** in synchronism with valve **213**.

The follower which cooperates with cam **5** opens and closes a switch **217** which through the electrically conductive leads **25** opens and closes a circuit to the valves

38 or 39, depending on which of the channels 8 or 9 is in its rest position. As was mentioned above, when channel 9 is in its rest position, as shown in the drawings, the circuit will be completed through valve 39 for distributing powder from tube 241 against the inner face of mold 15, while when channel 8 is in its rest position, the circuit will be completed through valve 38 for distributing powder through tube 242 to the inner surface of mold 15.

The structure of the invention as thus far described, is capable of continuously and cyclically operating the parts of the casting machine proper to produce a seamless pipe during each cycle. The operations which take place during one cycle are the following:

With the parts in the position shown in Fig. 1, let it be assumed that a completed part is about to be extracted from the mold 15 and that the operations for the manufacture of another pipe are about to commence. At this moment the extracting bar 19 is at a certain distance from the mold. The movement of bar 19 is independently controlled by pressing a button which is not a part of the machine itself. The mold is stationary and the carriage rests at the lowermost left hand portion of the base, as viewed in Fig. 1*a*. The ladle is stationary. It is supplied with material by structure independent of the machine and not shown in the drawings. All that is required is that the ladle 1′ be filled with a desired quantity of liquid material at the moment when the carriage 16″ has arrived at the rightmost point of its travel along the base of the machine, as viewed in Fig. 1*b*.

The shaft 7 which carries the cams rotates at a constant speed even while the parts of the casting machine proper are at rest, the cams having circular portions which do not move the followers during this time. During this stationary period of the casting machine proper, the finished pipe is removed by the extracting bar 19. When the mold 15 is empty, the shaft 7 has turned through an angle sufficient to cause the cam 6 to actuate the follower associated therewith for energizing motor 18 to drive the carriage 16″, and all parts carried thereby, up the base of the casting machine to the right, as viewed in Fig. 1*a*. During this movement of the carriage 16″ the channel 8 is received into the guide means 301 and into the mold 15 which continues to envelop the channel 8 to an increasing extent as the carriage 16″ moves to the right, as viewed in Fig. 1. Also, during this movement of carriage 16″, the right switch 36, as viewed in Fig. 2, is closed by the stationary rail 206 so that cooling material is sprayed from the right reservoir 20, as viewed in Fig. 2, against the inner face of channel 9, and as the carriage 16″ continues to move to the right, the reservoir 20 moves therewith so that the cooling material is distributed along the entire inner surface of channel 9. As was mentioned above, the left reservoir 20, as viewed in Fig. 2, cannot operate at this time because the left switch assembly 46 is open. Only the right switch assembly 46 is closed because channel 9 is located in its rest position. At a predetermined moment during the movement of the carriage 16″ up the base, the cam 2 actuates its follower to start rotation of motor 16 so as to rotate the mold 15 and during movement of the carriage the speed of rotation of the mold is increased until it is rotating at full speed at the moment when the carriage 16″ arrives at the end of its advancing movement along the base to the right, as viewed in Figs. 1*a* and 1*b*, the mold 15 continuously moving along and surrounding the channel 8 and the channel 9 being continuously cooled along its length during this time.

When the carriage has arrived at its rightmost position, as viewed in Fig. 1*b*, the switch 36 opens due to the upwardly curved right end portion of rail 206, as viewed in Fig. 1, so that the cooling of channel 9 stops at this time. The mold 15 continues to rotate. The ladle 1′ is filled with molten material ready to be poured into the mold, and at this moment the cam 1 actuates its follower to energize motor 201 for tilting the ladle forwardly. The liquid material flows along channels 10 and 8 toward the left end of the latter, as viewed in Fig. 1*b*, from which the material falls onto the inner surface of the rotating mold. The cam 5 closes the circuit through valve 39 just prior to arrival of molten metal at the inner surface of the mold, so that Fe-Si powder is distributed against the rotating inner surface of mold 15 just before the molten metal drops from channel 8 onto the rotating mold 15. The cam 6 then actuates motor 18 to reverse the movement of the carriage 16″ so that the latter now moves to the left, as viewed in Fig. 1*b*, toward the left end position shown in Fig. 1*a*, and during this leftward movement of the carriage and rotating mold 15 therewith, Fe-Si powder continues to be distributed against the inner surface of the mold and molten material continues to fall against the inner surface of the mold which uncovers channel 8 to an increasing extent during this part of the cycle.

At a predetermined point during the return of carriage 16″, the cam 1 actuates motor 201 to return the ladle 1′ to its rest position. If the ladle 1′ holds only enough molten material for one pipe, then the speed of the return movement of the ladle 1′ is of no consequence. However, when the ladle 1′ holds an amount of molten material sufficient for a plurality of pipes, the cam 1 is shaped to quickly return the ladle 1′ so as to sharply cut off the flow of molten material therefrom.

Shortly after the liquid material has stopped flowing from ladle 1′, the cam 5 opens the circuit through valve 39 to stop the distribution of Fe-Si powder.

When the carriage 16″ and guide means 301 are completely separated from channel 8, the cams 3 and 4 actuate valves 213 and 214 to reverse channels 8 and 9 together with channels 10 and 11, respectively, so that channels 11 and 9 assume the position previously occupied by channels 10 and 8, as was described above. The cam 2 stops the rotation of the mold after a time sufficient for the material therein to solidify, and thus a cycle of operations is completed. During the next cycle, the electric valve 38 will be energized and channels 11 and 9 will guide the material to the mold, while channel 8 is cooled on the opposite side of the machine.

The structure of the invention as thus far described is therefore capable of continuously operating to produce a plurality of seamless pipes one after the other in a fully automatic manner. However, it should be noted that the structure described above will be incapable of producing uniform pipes. Among the reasons for this are the following:

As the material dwells in the ladle 1′, it cools and its viscosity changes. The rate of cooling is not uniform since it is a well known fact that the molten material will cool at a much faster rate when it first becomes located in the ladle, and this rate of cooling then decreases. Furthermore, where the ladle 1′ holds an amount of material which is sufficient for more than one pipe, it is evident that the several pipes made from the charge held by ladle 1′ will be made from molten material having different temperatures and viscosities. Furthermore, it is difficult to control and predict the rate of flow of the material along the channels. Thus, it is inevitable that variable factors will arise which will prevent uniformity in the products produced by the apparatus, and where the parts of the casting machine proper are controlled so as to operate in a fixed, unchanging manner through several cycles, it is evident that lack of uniformity in the products will necessarily result.

The present invention includes a means for overcoming the latter drawbacks in a fully automatic manner which is uninfluenced by errors inherent in human judgment. Thus, it will be seen that the cams 1, 2 and 6 have camming surface portions which vary along the axis of the cams. Fig. 4*a* shows a cam 29 which may be used for one of the cams 1, 2 or 6. It is possible to machine the camming surfaces of these cams so that they will control the apparatus according to predetermined laws required by variations in the temperature and viscosity of the material, or, as is shown in Figs. 4 and 4*a*, each of the cams 1, 2 and 6 may be made up of a plurality of individual cam portions which are grouped together and angularly fixed to each other to rotate as a unit. The camming surface portions of the several cam portions smoothly merge into each other so that the followers will have no difficulty in cooperating with a shifting cam. In the particular embodiment disclosed in Fig. 4, the several cam portions of each cam are keyed together to a sleeve which is slidably keyed on the shaft 7 so that each of the cams 1, 2 and 6 is constrained to rotate with shaft 7 while being slidable therealong. As is shown in Fig. 4, the shaft 7 may be provided with notches cooperating with a spring connected to each cam for positively locating the cam in one of a number of positions along the shaft 7.

The support of the control apparatus shown in Fig. 4 includes a means for guiding and supporting the substantially U-shaped shifting members **104**, **106** and **108** for movement along a path parallel to the shaft **7**, member **104** embracing an edge portion of cam **1**, member **106** embracing an edge portion of cam **2**, and member **108** embracing an edge portion of cam **6**. Each of the shifting members is formed with a rack portion, and these rack portions respectively mesh with pinions driven by motors **105**, **107**, and **109**, respectively. Thus, motor **105** may be operated to shift member **104**, motor **107** may be operated to shift member **106**, and motor **109** may be operated to shift member **108**.

According to the present invention means are provided for detecting variations in properties of the molten material, such as the temperature and viscosity thereof, and this detecting means sends impulses to an electronic apparatus which evaluates and amplifies the impulses and which is electrically connected to the motors **105**, **107** and **109** for automatically operating the latter in a manner which automatically adjusts the cams **1**, **2** and **6** to variations in the properties of the liquid material, such as the temperature and viscosity thereof.

Thus, referring to Figs. 1*a* and 1*b*, it will be seen that a photoelectric cell **102** is arranged opposite the operating position of channels **10** and **11** to be influenced by light rays emanating from the molten material flowing down either of these channels. Also, an additional photoelectric cell **101** is located opposite the left end of mold **15** to be influenced by light rays emanating from molten material located in the mold **15**. The photoelectric cell **101** is carried by a lever which is mounted intermediate its ends on the left end of carriage **16″** for tilting movement about the pivot pin **221**. Thus, the photoelectric cell **101** moves together with the carriage **16″**. A support **231** is fixed to the base, extends upwardly therefrom and carries at its upper end a pin **230** which is located above pin **221** in the path of movement of the lever carrying photoelectric cell **101**, as carriage **16″** moves to the left, as viewed in Fig. 1*a*, back to its rest position. Therefore, just before the carriage **16″** reaches its rest position, the lever carrying cell **101** will move with respect to pin **230** to cause the latter to tilt cell **101** in a clockwise direction about pivot **221** to the position shown in solid lines in Fig. 1*a*, so that the cell **101** does not interfere with the operation of the pipe extracting bar **19**. When the carriage **16″** is located anywhere to the right of a position located slightly to the right of that shown in Fig. 1*a*, the photoelectric cell **101** will by gravity automatically assume the position shown in dot-dash lines so that it will be influenced by light rays emanating from molten material located in the mold **15**. The leads connected to photocell **101** are of course flexible so as not to interfere with the tilting movement of the cell. Thus, the cell **102** will be influenced by the molten material at a time interval prior to influence of cell **101** by the molten material, so that the cells **101** and **102** can measure the rate of flow of the molten material and therefore give an indication of the viscosity thereof.

Furthermore, a pyrometer **120** is fixed to the top of ladle **1′** and extends into the latter to measure the temperature of the molten material, the electrical leads to the pyrometer also being flexible so that the pyrometer is free to tilt with the ladle **1′**. The impulses received by and delivered from photocells **101** and **102** and pyrometer **120** are sent to an electronic installation **103** similar to the electronic installation A described above. The electronic installation **103** evaluates and amplifies the impulses received from elements **101**, **102**, and **120** and is electrically connected by lines **111**, **112**, and **113** to the motors **109**, **107**, and **105**, respectively, and the electronic apparatus **103** is supplied with current by the lines **110** which are connected to any source of alternating current. Thus, the motors **105**, **107**, and **109** are automatically operated to shift cams **1**, **2** and **6**, respectively, in a manner which automatically adjusts these cams to variations in the properties of the material handled by the machine, and in this way it is possible with the apparatus of the invention to produce uniform products in a fully automatic manner. Thus, without the detecting means of the invention, the electronic installation for evaluating and amplifying the impulses received from the detecting means, and the structure operated by this electronic installation for shifting the cams **1**, **2**, and **6**, it would not be possible to produce uniform products. For example, if the ladle is tilted during each cycle through the same angle and at the same speed and if the carriage **16″** moves back to its rest position at the same speed during each cycle, it is evident that as the temperature of the molten material decreases and the viscosity thereof increases less molten material will flow from the ladle and the distribution of the molten material along the mold will necessarily vary from cycle to cycle. With the structure of the invention, however, the ladle is tilted to a greater degree and held tilted for a longer period of time in a fully automatic manner as the temperature of the material drops, this control being derived from the pyrometer, and also the rate of movement of the carriage **16″** back to its rest position is decreased in a fully automatic manner as the viscosity of the molten material increases, this latter control being derived from the photoelectric cells, so that absolute uniformity of the products is assured with the structure of the invention.

It should be noted that the above described details of the detecting means may be varied. For example, instead of the photoelectric cells, it is possible to arrange switches along the path of flow of the molten material, these switches having movable arms entrained by the flowing material to successively close the switches so that the time interval between closing of successive switches gives an indication of the viscosity of the material. Also, the flowing material might entrain a movable member which actuates a variable resistor to indicate the viscosity of the material. Or, it is possible to measure the distance travelled by an object which melts at a predetermined known temperature in order to determine the viscosity and/or temperature of the material.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of casting machines differing from the types described above.

While the invention has been illustrated and described as embodied in automatic centrifugal casting machines, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. An automatic casting machine for forming an object of desired shape from a liquid material which solidifies upon cooling, comprising, in combination, a plurality of machine elements constituting a casting machine proper; automatic operating means operatively connected to said machine elements for automatically, continuously and cyclically operating the same at predetermined speeds, for predetermined durations, and in a predetermined sequence during each cycle; detecting means mounted on the machine for detecting variations in the properties of the liquid material during handling thereof by said machine elements; adjusting means operatively connected to said operating means for adjusting the latter to regulate said speeds and durations; and actuating means connecting said detecting means to said adjusting means for automatically actuating the latter to compensate for material variations detected by said detecting means, whereby a uniform object is automatically produced during each cycle irrespective of variations in the properties of the liquid material during handling thereof by the machine.

2. An automatic casting machine for forming an object of desired shape from a liquid material which solidifies upon cooling, comprising, in combination, a plurality of machine elements constituting a casting machine proper; automatic operating means operatively connected to said machine elements for automatically, continuously and cyclically operating the same at predetermined speeds, for predetermined durations, and in a predetermined sequence during each cycle; and compensating means operatively connected to said operating means for automatically adjusting the latter in a manner which compensates for variations in the properties of the liquid material handled by the machine, whereby a uniform object is automatically produced during each cycle irrespective of variations in the properties of the liquid material during handling thereof by the machine.

3. A machine as defined in claim 1 and wherein said operating means includes at least one cam member having a camming profile which varies along the axis of said cam member and a follower member engaging said profile, said adjusting means engaging at least one of said members for shifting the same axially with respect to the other of said members.

4. An automatic casting machine for forming an object of desired shape from a liquid material which solidifies upon cooling, comprising, in combination, a plurality of machine elements constituting a casting machine proper; automatic operating means operatively connected to said machine elements for automatically, continuously and cyclically operating the same at predetermined speeds, for predetermined durations, and in a predetermined sequence during each cycle; detecting means mounted on the machine for detecting variations in the viscosity of the liquid material during handling thereof by said machine elements; adjusting means operatively connected to said operating means for adjusting the latter to regulate said speeds and durations; and actuating means connecting said detecting means to said adjusting means for automatically actuating the latter to compensate for viscosity variations detected by said detecting means, whereby a uniform object is automatically produced during each cycle irrespective of variations in the viscosity of the liquid material during handling thereof by the machine.

5. An automatic casting machine for forming an object of desired shape from a liquid material which solidifies upon cooling, comprising, in combination, a plurality of machine elements constituting a casting machine proper; automatic operating means operatively connected to said machine elements for automatically, continuously and cyclically operating the same at predetermined speeds, for predetermined durations, and in a predetermined sequence during each cycle; detecting means mounted on the machine for detecting variations in the temperature of the liquid material during handling thereof by said machine elements; adjusting means operatively connected to said operating means for adjusting the latter to regulate said speeds and durations; and actuating means connecting said detecting means to said adjusting means for automatically actuating the latter to compensate for temperature variations detected by said detecting means, whereby a uniform object is automatically produced during each cycle irrespective of variations in the temperature of the liquid material during handling thereof by the machine.

6. An automatic casting machine for forming an object of desired shape from a liquid material which solidifies upon cooling, comprising, in combination, a plurality of machine elements constituting a casting machine proper; automatic operating means operatively connected to said machine elements for automatically, continuously and cyclically operating the same at predetermined speeds, for predetermined durations, and in a predetermined sequence during each cycle, said operating means including a support, a shaft rotatably carried by said support, a cam having a camming profile which varies along the axis of the cam mounted on said shaft for rotation therewith and for shifting movement therealong, and a follower engaging said cam; electrical detecting means mounted on the machine for detecting variations in the properties of the liquid material during handling thereof by said machine elements; adjusting means operatively connected to said operating means for adjusting the latter to regulate said speeds and durations, at least a part of said adjusting means engaging said cam for shifting the latter along said shaft; and actuating means connecting said detecting means to said adjusting means for automatically actuating the latter to compensate for material variations detected by said detecting means, whereby a uniform object is automatically produced during each cycle irrespective of variations in the properties of the liquid material during handling thereof by the machine.

7. A machine as defined in claim 1 and wherein said detecting means includes photoelectric cells spaced from each other and influenced by light rays from the liquid material to measure the speed of flow thereof.

8. A machine as defined in claim 1 and wherein said detecting means includes photoelectric cells spaced from each other and influenced by light rays from the liquid material to measure the speed of flow thereof, and a pyrometer for measuring the temperature of the liquid material.

9. An automatic casting machine for forming an object of desired shape from a liquid material which solidifies upon cooling, comprising, in combination, a plurality of machine elements constituting a casting machine proper; automatic operating means operatively connected to said machine elements for automatically, continuously and cyclically operating the same at predetermined speeds, for predetermined durations, and in a predetermined sequence during each cycle, said operating means including a support, a shaft rotatably carried by said support, a cam having a camming profile which varies along the axis of the cam mounted on said shaft for rotation therewith and for shifting movement therealong, and a follower engaging said cam; electrical detecting means mounted on the machine for detecting variations in the properties of the liquid material during handling thereof by said machine elements; adjusting means operatively connected to said operating means for adjusting the latter to regulate said speeds and durations, at least a part of said adjusting means engaging said cam for shifting the latter along said shaft; and actuating means connecting said detecting

means to said adjusting means for automatically actuating the latter to compensate for material variations detected by said detecting means, whereby a uniform object is automatically produced during each cycle irrespective of variations in the properties of the liquid material during handling thereof by the machine, said actuating means including an electronic apparatus for receiving impulses from said detecting means, for interpreting and for amplifying the impulses, and an electrical moving means operated by said electronic apparatus and connected to said part of said adjusting means for moving said part in accordance with said impulses.

10. An automatic casting machine for forming an object of desired shape from a liquid material which solidifies upon cooling, comprising, in combination, a plurality of machine elements constituting a casting machine proper; automatic operating means operatively connected to said machine elements for automatically, continuously and cyclically operating the same at predetermined speeds, for predetermined durations, and in a predetermined sequence during each cycle, said operating means including a support, a shaft rotatably carried by said support, a cam having a camming profile which varies along the axis of the cam mounted on said shaft for rotation therewith and for shifting movement therealong, and a follower engaging said cam; electrical detecting means mounted on the machine for detecting variations in the properties of the liquid material during handling thereof by said machine elements; adjusting means operatively connected to said operating means for adjusting the latter to regulate said speeds and durations, at least a part of said adjusting means engaging said cam for shifting the latter along said shaft; and actuating means connecting said detecting means to said adjusting means for automatically actuating the latter to compensate for material variations detected by said detecting means, whereby a uniform object is automatically produced during each cycle irrespective of variations in the properties of the liquid material during handling thereof by the machine, said actuating means including an electronic apparatus for receiving impulses from said detecting means, for interpreting and for amplifying the impulses, and an electrical moving means operated by said electronic apparatus and connected to said part of said adjusting means for moving said part in accordance with said impulses, said moving means comprising a rack connected to said part of said adjusting means, a pinion meshing with said rack, and an electric motor operatively connected to said pinion for rotating the latter.

11. In an automatic casting apparatus for forming an object of desired shape from a liquid material which solidifies upon cooling, in combination, a suport; a shaft turnably carried by said suport; drive means connected to said shaft for rotating the latter; a cam mounted on said shaft for rotation therewith and for shifting movement therealong, said cam having a camming profile which varies along the axis of said cam; a follower engaging said cam to be moved thereby; variable resistor means operatively connected to said follower to be operated thereby; a motor connected to a part of the apparatus for operating said part; an electrical circuit including said motor and variable resistor means, so that the operation of said motor is controlled by said cam and follower; shifting means engaging said cam for shifting the latter along said shaft with respect to said follower so as to change the camming profile which engages said follower to thereby change the operation of said motor; detecting means connected to the apparatus for detecting variations in the properties of the liquid material handled by the apparatus; and transmission means operatively connected to said detecting means to receive therefrom indications of property variations in the liquid material and operatively connected to said shifting means to transmit said indications to the latter and to operate the latter to shift said cam in a manner which compensates for variations in the properties of the liquid material.

12. In an automatic casting apparatus for forming an object of desired shape from a liquid material which solidifies upon cooling, in combination, a support; a shaft turnably carried by said support; drive means connected to said shaft for rotating the latter; a cam mounted on said shaft for rotation therewith and for shifting movement therealong, said cam having a camming profile which varies along the axis of said cam; a follower engaging said cam to be moved thereby; variable resistor means operatively connected to said follower to be operated thereby; a motor connected to a part of the apparatus for operating said part; an electrical circuit including said motor and variable resistor means, so that the operation of said motor is controlled by said cam and follower; shifting means engaging said cam for shifting the latter along said shaft with respect to said follower so as to change the camming profile which engages said follower to thereby change the operation of said motor; electrical detecting means connected to the apparatus for detecting variations in the properties of the liquid material handled by the apparatus; and electronic means connected to said detecting means for receiving, interpreting, and amplifying impulses received from said detecting means, said electronic means being operatively connected to said shifting means for operating the latter in accordance with impulses received from said detecting means, whereby the operation of said motor is automatically adjusted to variations in the properties of the liquid material.

13. In an automatic casting apparatus for forming an object of desired shape from a liquid material which solidifies upon cooling, in combination, a support; a shaft turnably carried by said support; drive means connected to said shaft for rotating the latter; a cam mounted on said shaft for rotation therewith and for shifting movement therelong, said cam having a camming profile which varies along the axis of said cam; a follower engaging said cam to be moved thereby; variable resistor means operatively connected to said follower to be operated thereby; a motor connected to a part of the apparatus for operating said part; an electrical circuit including said motor and variable resistor means, so that the operation of said motor is controlled by said cam and follower; a U-shaped shifting member embracing an edge portion of said cam and being mounted on said support for movement along a path parallel to said shaft; rack means connected to said shifting member for movement therewith; a pinion meshing with said rack means; a second motor connected to said pinion to rotate the latter; electrical detecting means connected to the apparatus for detecting variations in the properties of the liquid material handled by the apparatus; and electronic means operatively connected to said detecting means for receiving, interpreting, and amplifying impulses of said detecting means and being operatively connected to said second motor for operating the latter in accordance with said impulses, whereby said shifting member is automatically moved along said path to shift said cam for automatically adjusting the operation of said first-mentioned motor to variations in the properties of the liquid material handled by the apparatus.

14. In an apparatus as defined by claim 13, said apparatus including guide means for guiding the liquid material along a predetermined path and said detecting means including a pair of photoelectric cells located opposite spaced portions of said guide means to be influenced by light rays emanating from the liquid material for measuring the speed of flow of the liquid material so as to detect variations in the viscosity thereof.

15. In an apparatus as defined by claim 13, said detecting means including a pyrometer adapted to engage

the liquid material for detecting variations in the temperature thereof.

16. In an apparatus for automatically forming objects of a desired shape from a liquid material which solidifies upon cooling, in combination, an elongated base; a carriage mounted on said base for movement therealong; a first motor operatively connected to said carriage for driving the latter along said base; an elongated hollow mold turnably carried by said carriage; a second motor also carried by said carriage and being operatively connected to said mold for rotating the latter on said carriage; a ladle tiltably carried by said base and being spaced from said carriage; a third motor operatively connected to said ladle for tilting the latter; channel means carried by said base and located at one end next to said ladle to receive liquid material therefrom; an electrical circuit connected to said first, second and third motors for energizing the same and including first, second, and third variable resistors respectively connected electrically to said first, second and third motors for controlling the operation thereof; first, second, and third cam followers operatively connected to said first, second and third variable resistors, respectively, for operating the latter; support means movably supporting said followers; first cam means engaging said first follower for moving the latter to operate said first variable resistor in a manner which operates said first motor to drive said carriage up to said channel means to locate said mold in a position to receive liquid material from said channel means and away from said channel means after liquid material is located in said mold, during rotation of said first cam means, the latter having a camming profile which varies along the axis of said first cam means; second cam means engaging said second follower for moving the latter to operate said second variable resistor in a manner which operates said second motor to rotate said mold until the liquid material solidifies in said mold, during rotation of said second cam means, the latter having a camming profile which varies along the axis of said second cam means; third cam means operatively engaging said third follower to move the latter to operate said third variable resistor in a manner which operates said third motor to tilt said ladle when said carriage is in said position, for delivering liquid material to said channel means to be received by said mold, during rotation of said third cam means, said third cam means having a camming profile which varies along the axis of said third cam means; a shaft turnably carried by said support means and carrying said first, second and third cam means for rotation with said shaft and for shifting movement along said shaft; drive means connected to said shaft for rotating the latter; first, second and third electrical shifting means respectively located next to said first, second and third cam means for shifting the latter along said shaft; electrical detecting means mounted on the apparatus for detecting variations in the properties of the liquid material handled by the apparatus; and electronic means electrically connected to said detecting means for receiving impulses therefrom and for interpreting and amplifying said impulses and being electrically connected to said first, second and third shifting means for automatically operating the latter in accordance with impulses received from said detecting means to automatically shift said first, second and third cam means along said shaft for automatically adjusting the operation of said first, second and third motors to variations in the properties of the liquid material, whereby uniform objects are automatically produced by the apparatus irrespective of variations in the properties of the liquid material.

17. In an apparatus as defined in claim 16, said channel means comprising a pair of elongated channel portions located next to each other; electrically operable moving means operatively connected to said channel portions for alternately moving the latter to and from an operating position; a switch electrically connected to said moving means for opening and closing a circuit to the latter; a fourth follower operatively connected to said switch for closing and opening the latter and being movably carried by said support means; and fourth cam means carried by said shaft for rotation therewith and engaging said follower for moving the latter in a manner which operates said moving means to move one of said channel portions to said operating position and the other of said channel portions away from said operating position after a cycle of operations is completed.

18. In an apparatus as defined in claim 17, and a cooling means carried by said carriage for cooling each channel portion when it is out of said operating position thereof.

19. In an apparatus as defined in claim 16, said apparatus including an electrically operable distributing means connected into said electrical circuit for distributing a powder against the inner surface of said mold; a switch electrically connected to said distributing means for opening and closing a circuit to the latter; a fourth follower operatively connected to said switch for closing and opening the latter and being movably carried by said support means; and fourth cam means carried by said shaft for rotation therewith and engaging said follower for moving the latter in a manner which operates said distributing means to apply powder to the inner surface of said mold just prior to the arrival of liquid material at the inner surface of said mold.

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