

May 31, 1955

S. O. EVANS ET AL

2,709,284

CONTROL APPARATUS FOR AND METHOD OF CONTINUOUS CASTING

Filed March 28, 1950

10 Sheets-Sheet 1

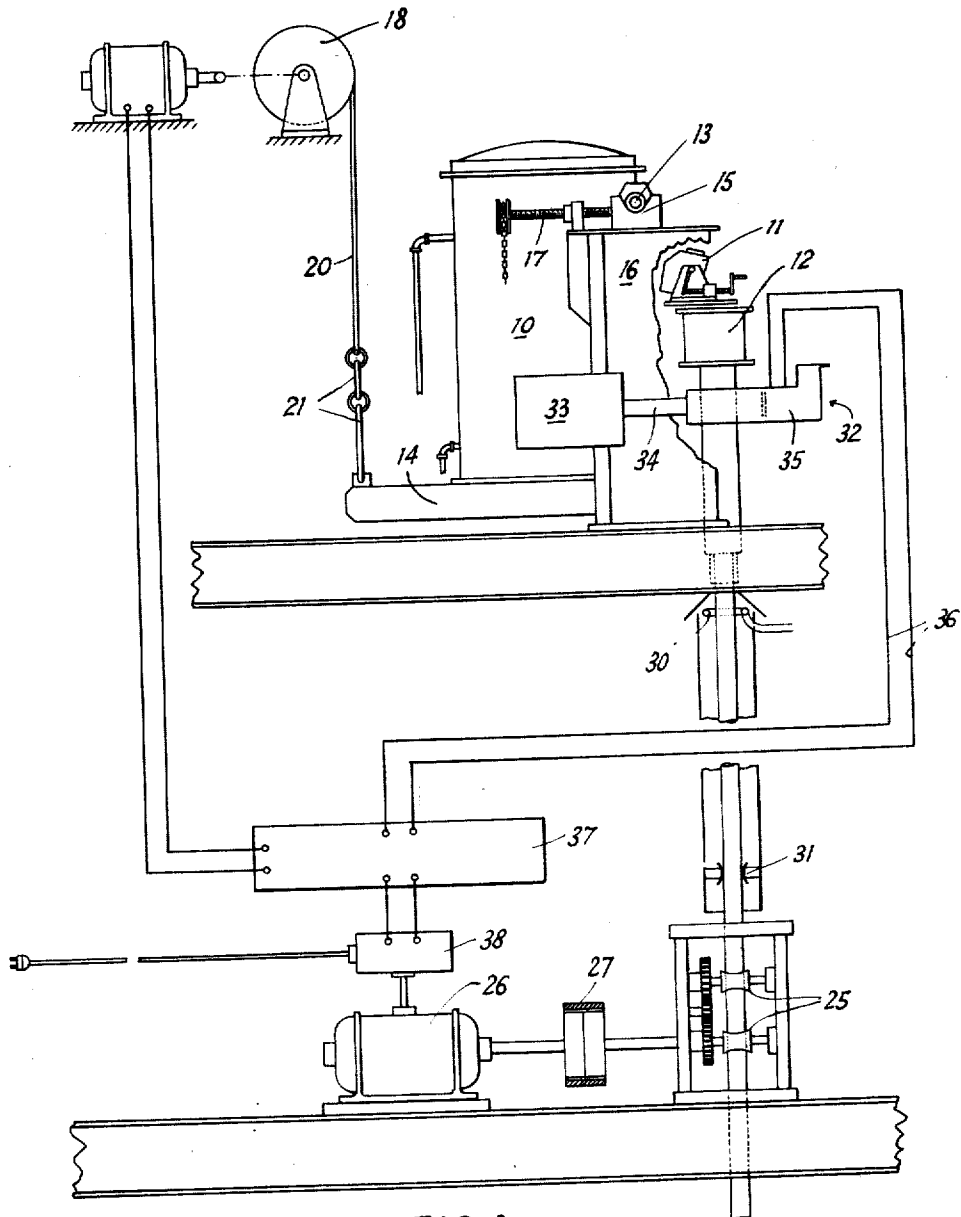


FIG. 1

INVENTORS
SIDLEY O. EVANS &
BY ISAAC HARTER, JR.
J. P. Moian
ATTORNEY

May 31, 1955

S. O. EVANS ET AL

2,709,284

CONTROL APPARATUS FOR AND METHOD OF CONTINUOUS CASTING

Filed March 28, 1950

10 Sheets-Sheet 2

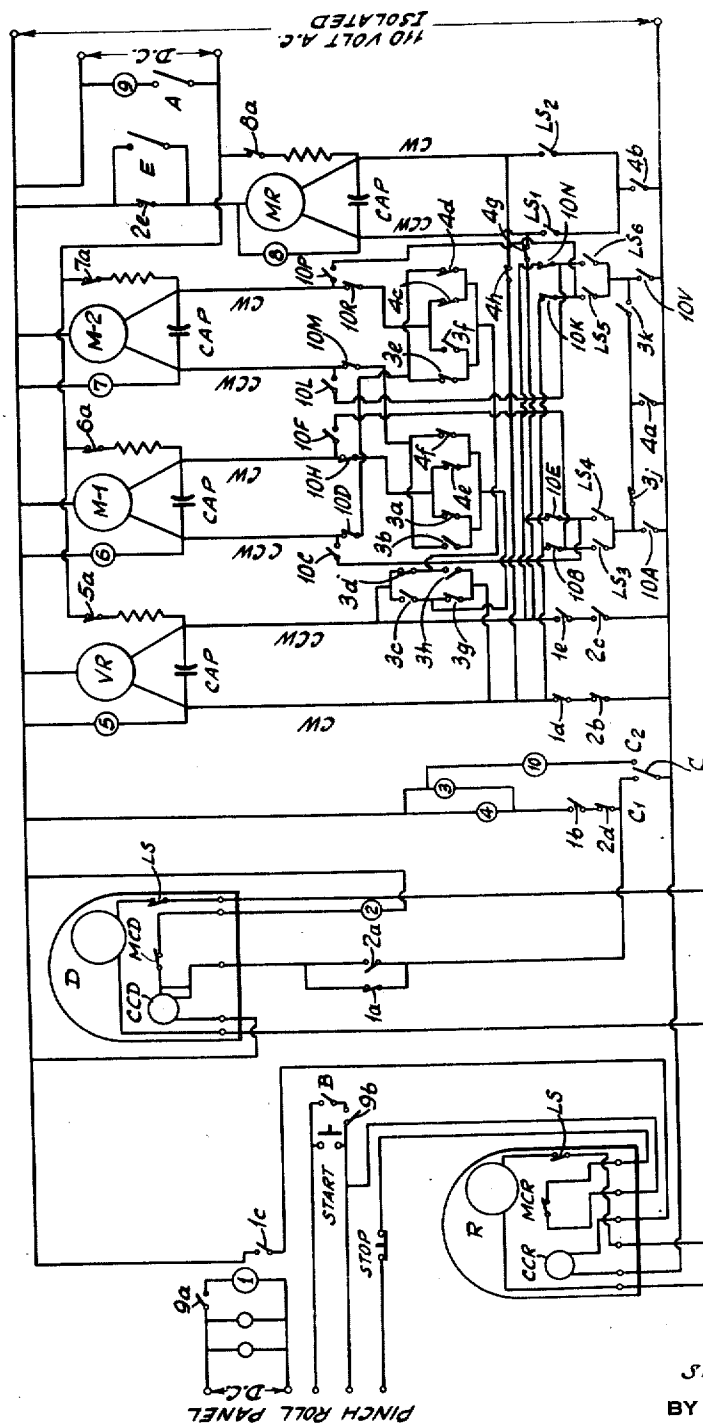


FIG. 2

INVENTOR
SIDLEY O. EVANS &
ISAAC HARPER, JR.
BY
J. P. Moran
ATTORNEY

May 31, 1955

S. O. EVANS ET AL

2,709,284

CONTROL APPARATUS FOR AND METHOD OF CONTINUOUS CASTING

Filed March 28, 1950

10 Sheets-Sheet 3

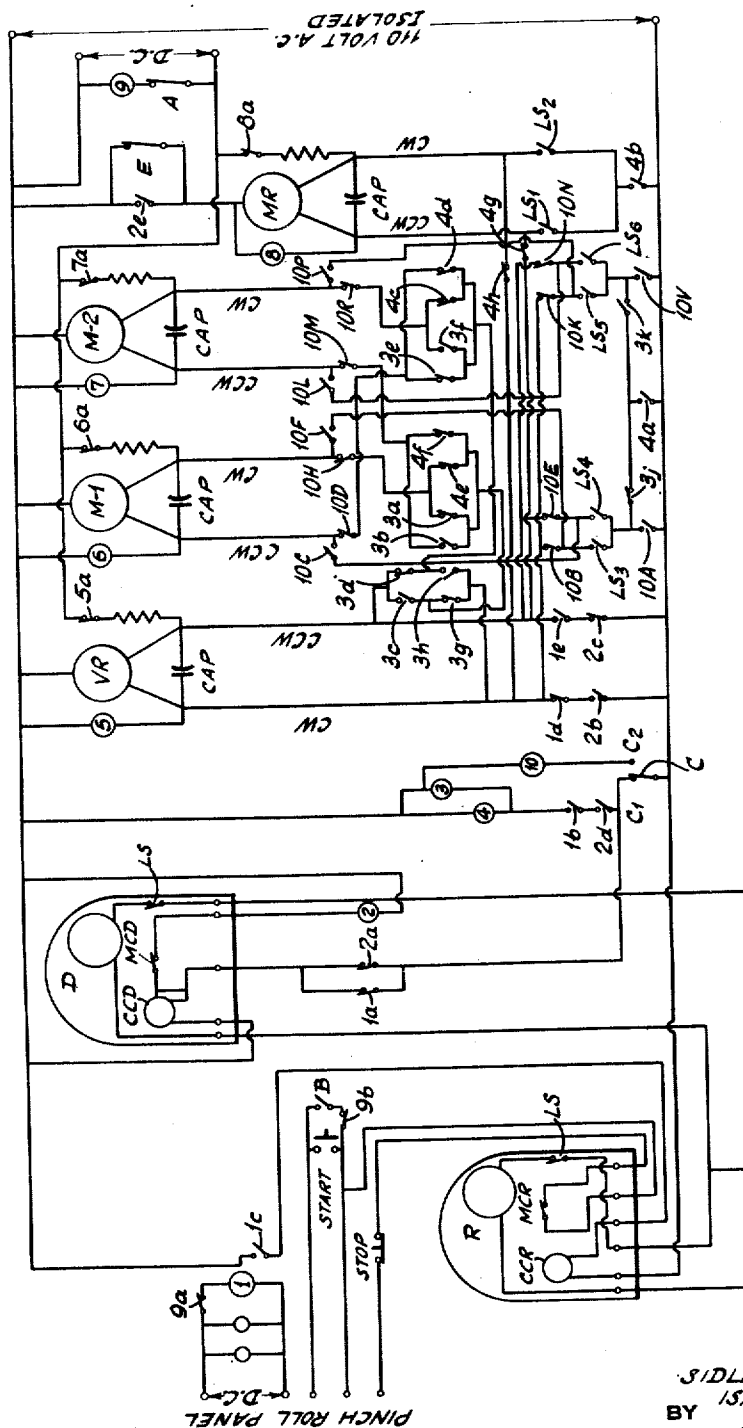


FIG. 3

INVENTOR
SIDLEY O. EVANS &
ISAAC HARTER, JR.
BY *[Signature]*
ATTORNEY

May 31, 1955

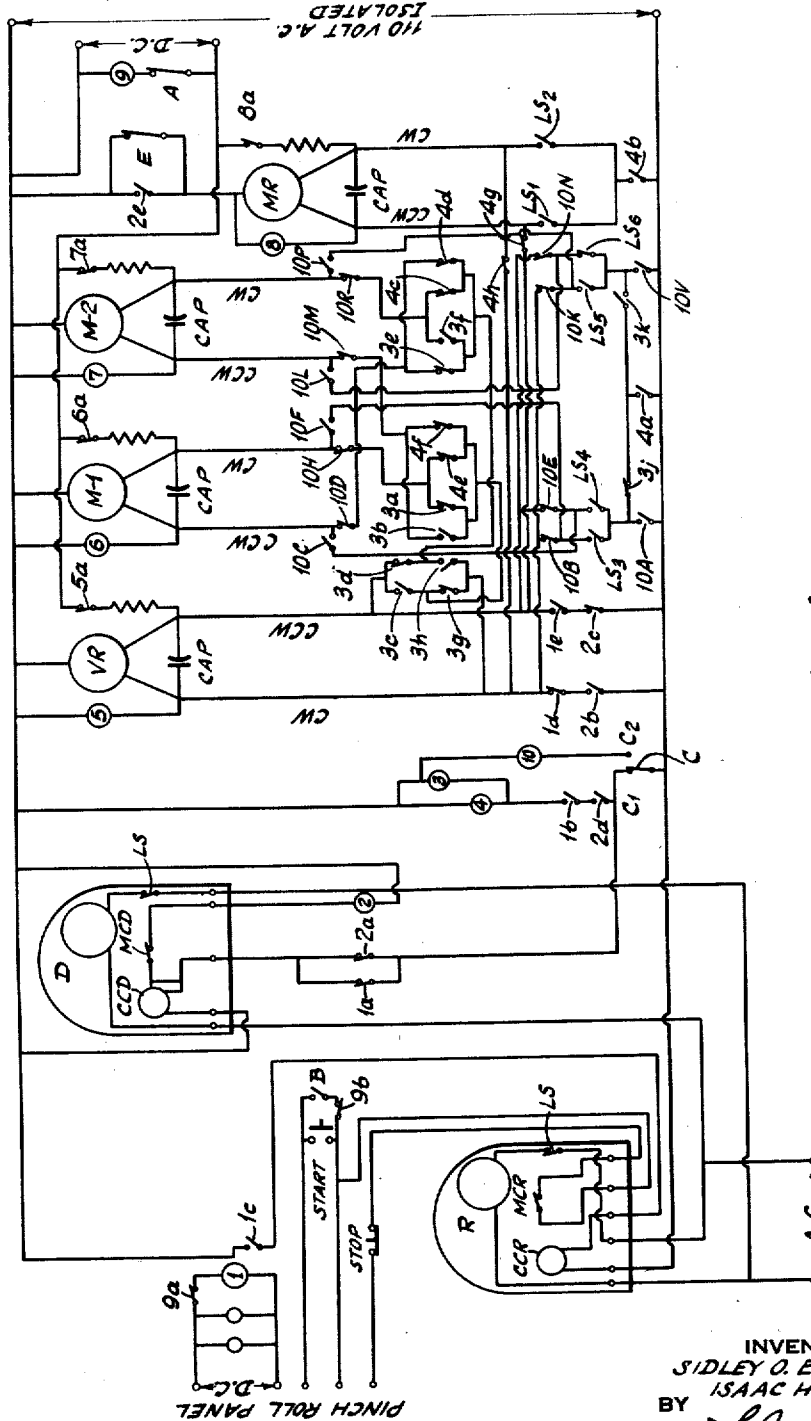
S. O. EVANS ET AL

2,709,284

CONTROL APPARATUS FOR AND METHOD OF CONTINUOUS CASTING

Filed March 28, 1950

10 Sheets-Sheet 4



May 31, 1955

S. O. EVANS ET AL

2,709,284

CONTROL APPARATUS FOR AND METHOD OF CONTINUOUS CASTING

Filed March 28, 1950

10 Sheets-Sheet 5

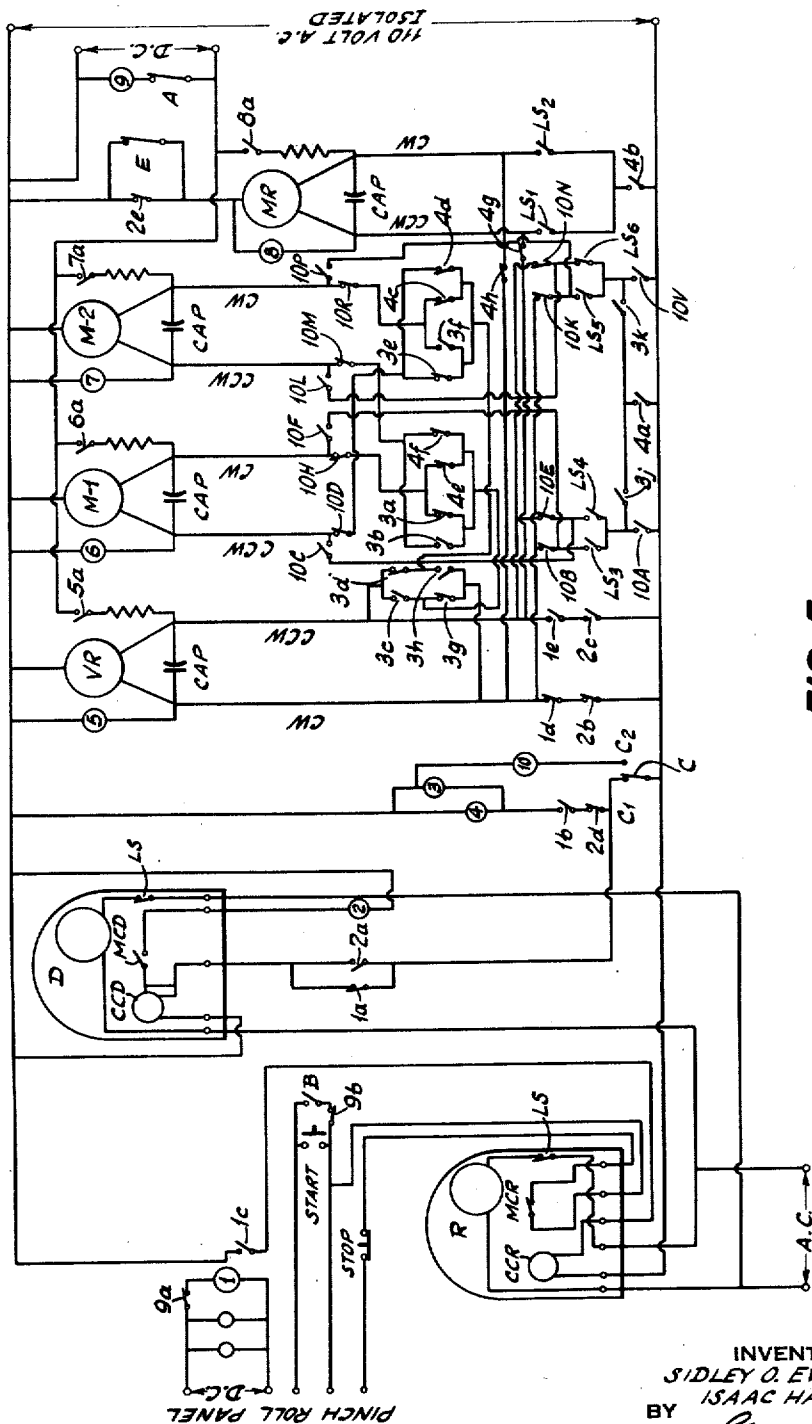


FIG. 5

INVENTOR
SIDLEY O. EVANS &
ISAAC HARTER, JR.
BY
J. Moran
ATTORNEY

May 31, 1955

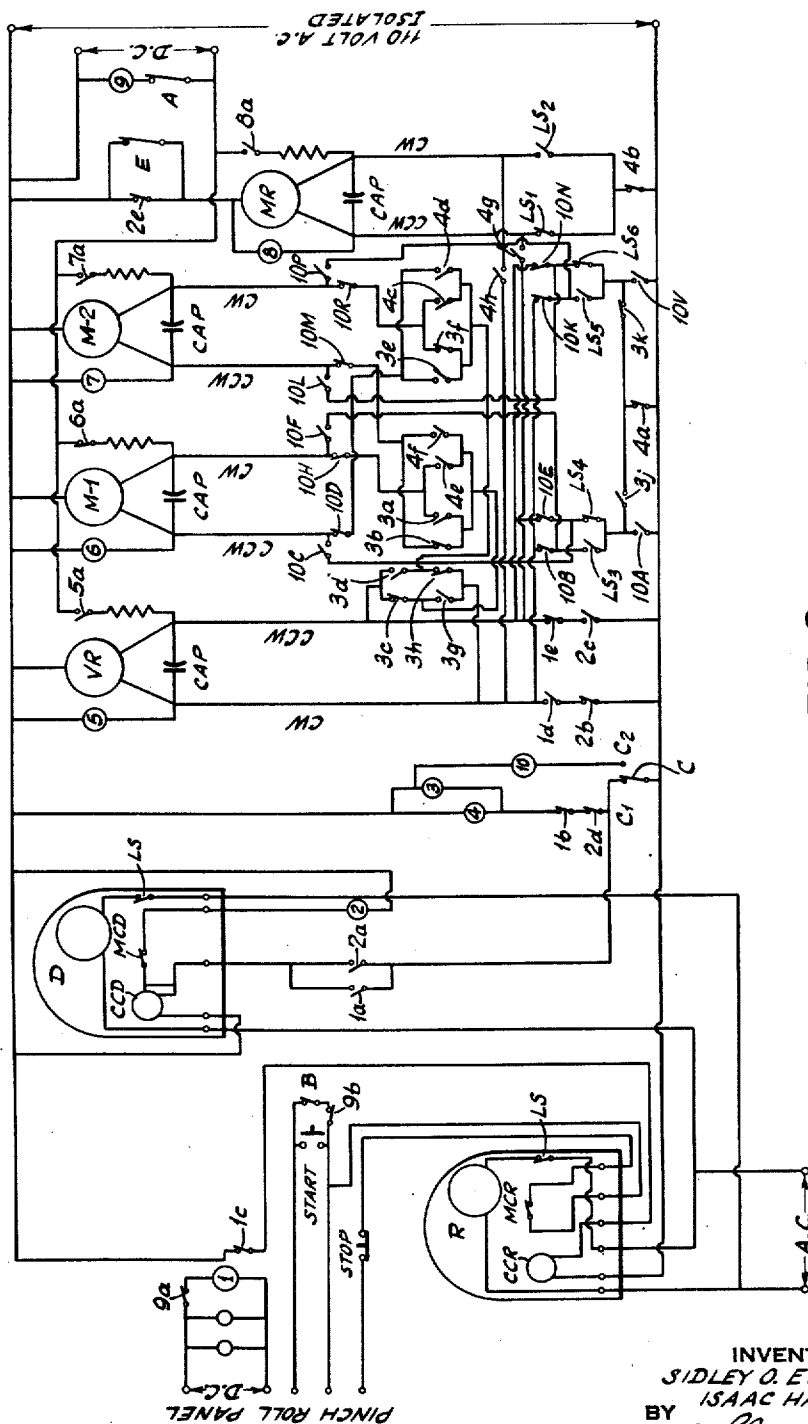
S. O. EVANS ET AL

2,709,284

CONTROL APPARATUS FOR AND METHOD OF CONTINUOUS CASTING

Filed March 28, 1950

10 Sheets-Sheet 6



INVENTOR
SIDLEY O. EVANS &
ISAAC HARTER, JR.
BY *J. P. Moran*
ATTORNEY

May 31, 1955

S. O. EVANS ET AL

2,709,284

CONTROL APPARATUS FOR AND METHOD OF CONTINUOUS CASTING

Filed March 28, 1950

10 Sheets-Sheet 7

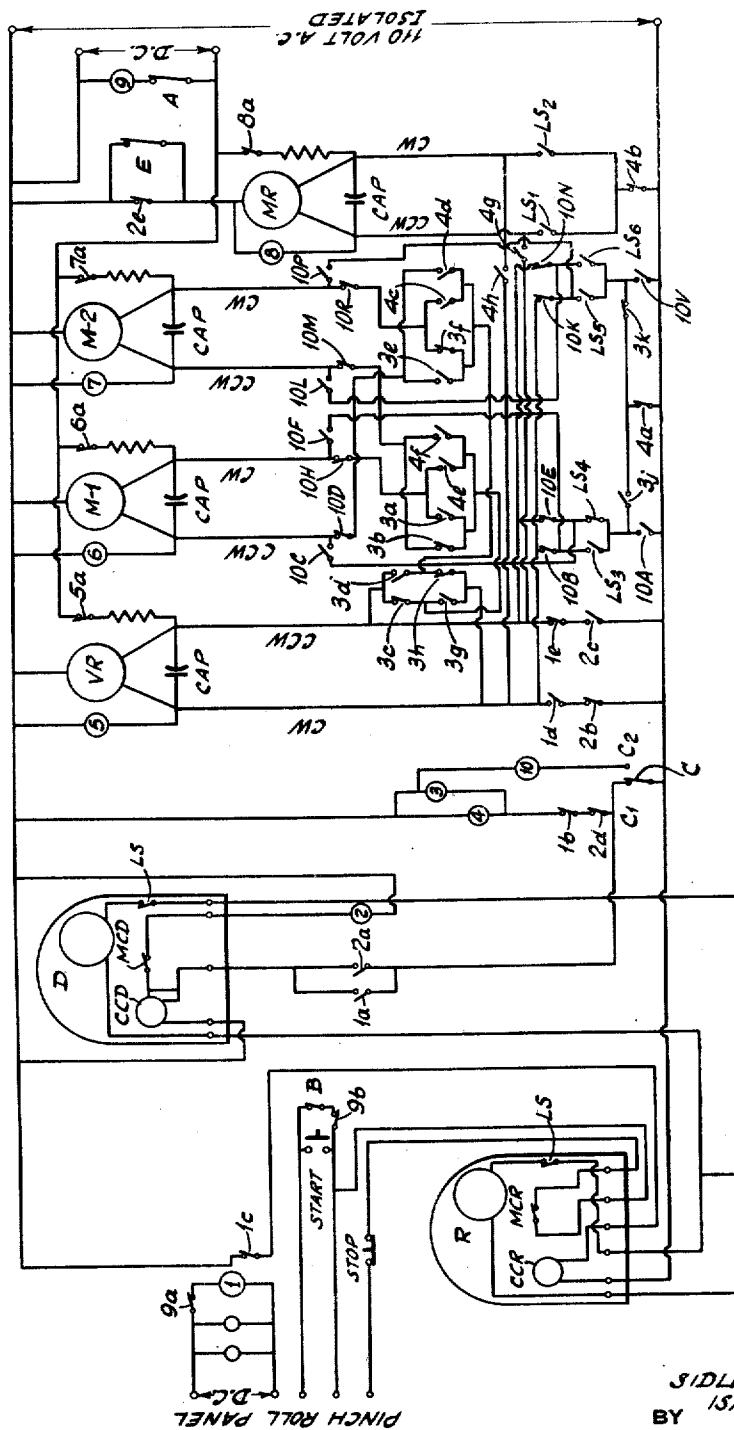


FIG. 7

INVENTOR
SIDLEY O. EVANS &
ISAAC HARTER, JR.
BY *J. P. Moran*
ATTORNEY

May 31, 1955

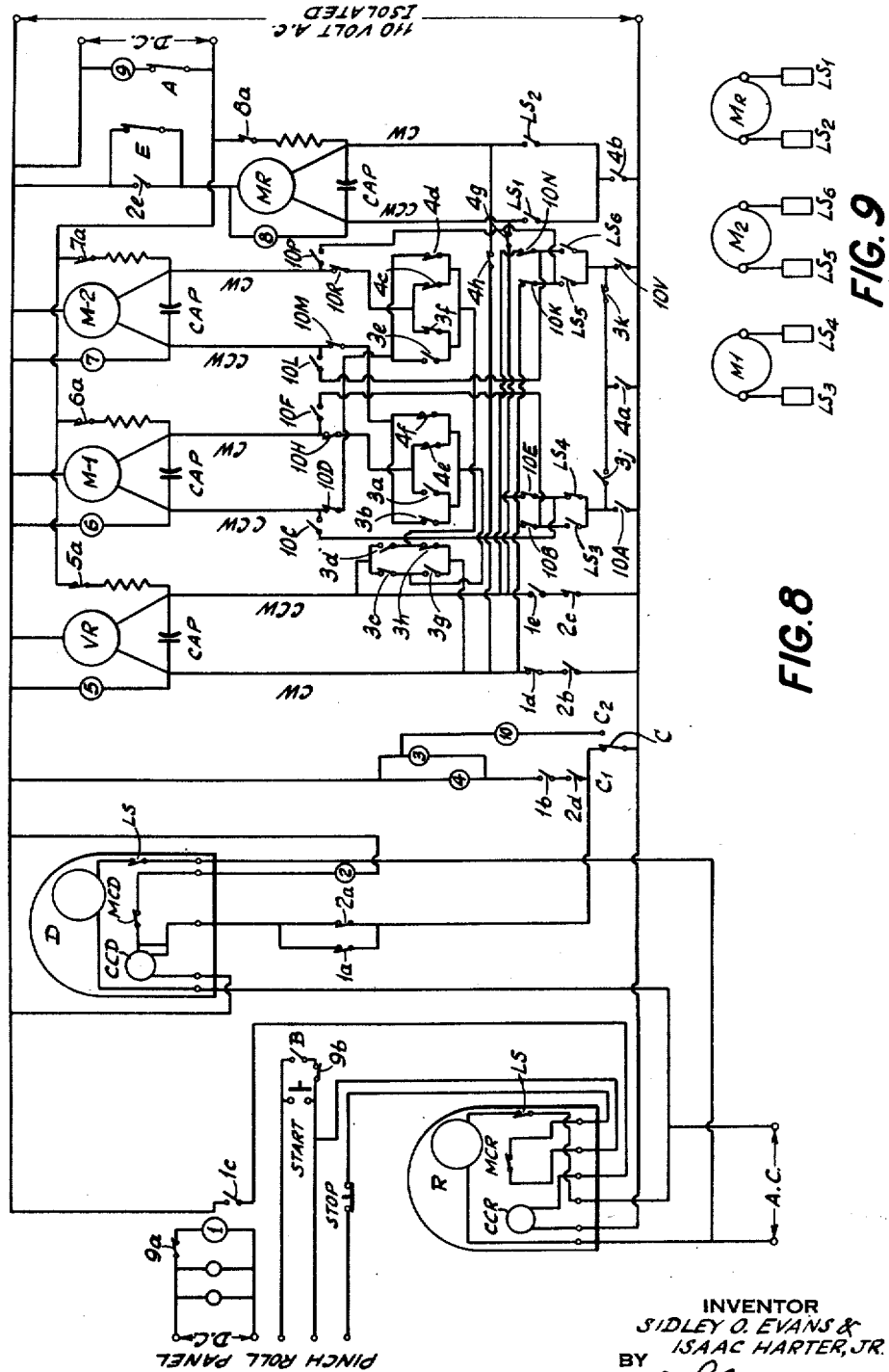
S. O. EVANS ET AL

2,709,284

CONTROL APPARATUS FOR AND METHOD OF CONTINUOUS CASTING

Filed March 28, 1950

10 Sheets-Sheet 8



May 31, 1955

S. O. EVANS ET AL

2,709,284

CONTROL APPARATUS FOR AND METHOD OF CONTINUOUS CASTING

Filed March 28, 1950

10 Sheets-Sheet 9

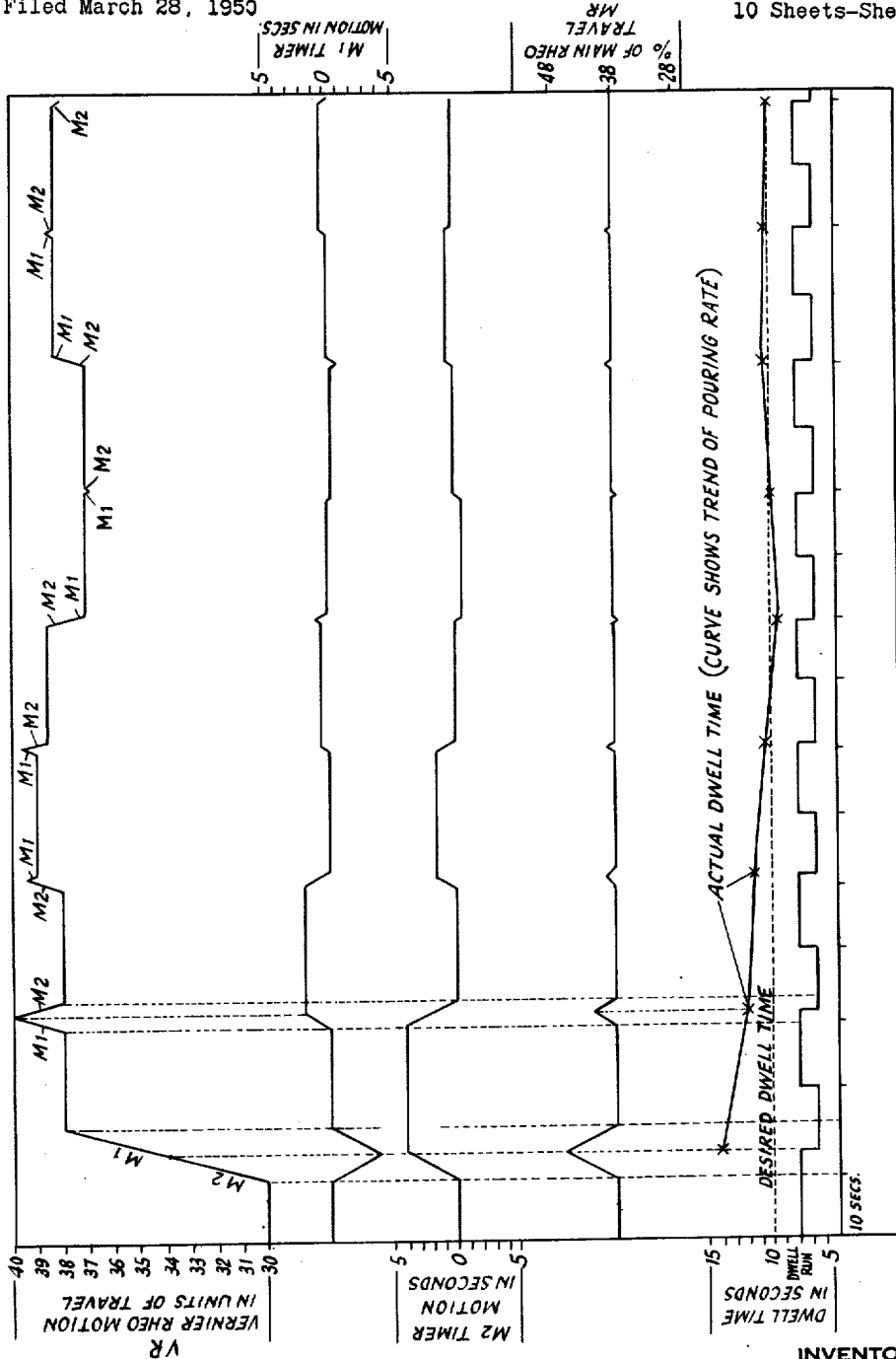


FIG. 10

INVENTORS
SIDLEY O. EVANS &
BY ISAAC HARTER, JR.
ATTORNEY

May 31, 1955

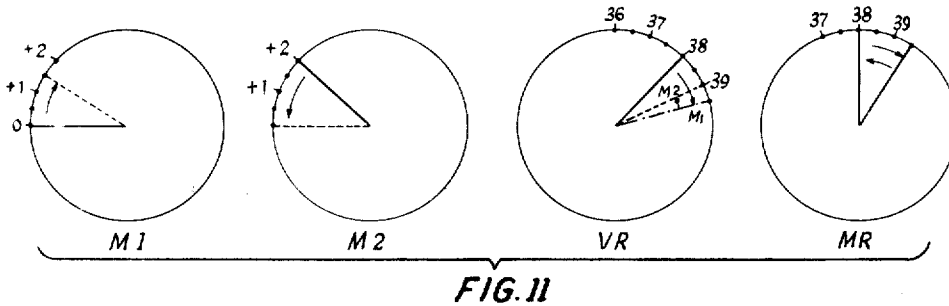
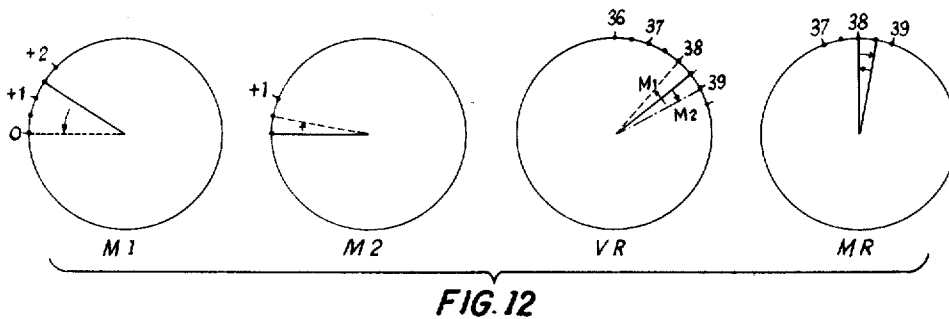
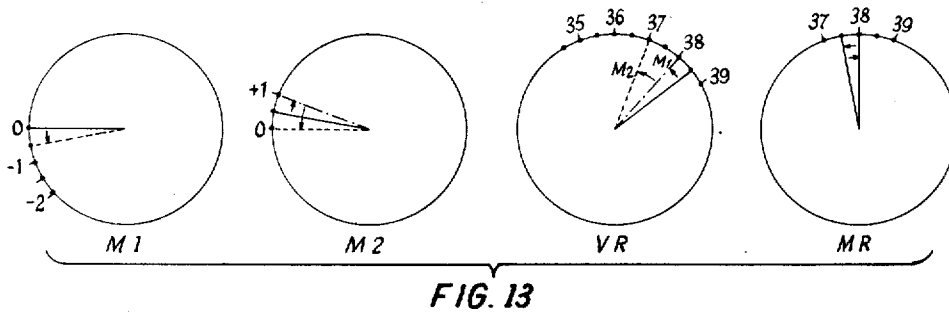
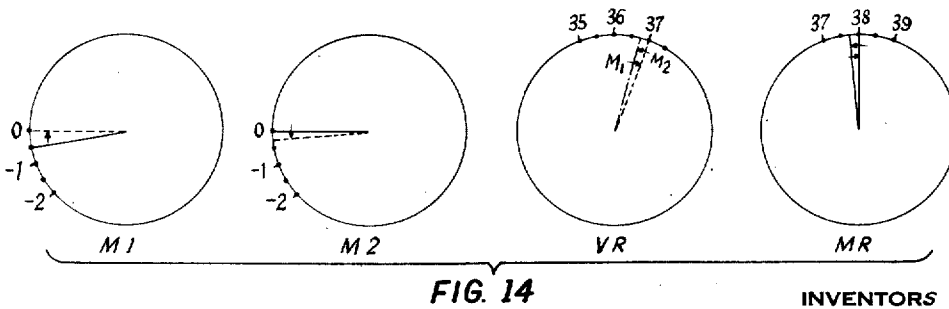
S. O. EVANS ET AL

2,709,284

CONTROL APPARATUS FOR AND METHOD OF CONTINUOUS CASTING

Filed March 28, 1950

10 Sheets-Sheet 10



INVENTORS
SIDLEY O. EVANS &
BY ISAAC HARTER, JR.
J. P. Moran
ATTORNEY

1

2,709,284

CONTROL APPARATUS FOR AND METHOD OF CONTINUOUS CASTING

Sidley O. Evans, Beaver Falls, and Isaac Harter, Jr., Beaver, Pa., assignors, by mesne assignments, to The Babcock & Wilcox Company, Jersey City, N. J., a corporation of New Jersey

Application March 28, 1950, Serial No. 152,404

19 Claims. (Cl. 22—57.2)

The present invention relates to electrical control systems, and more particularly to control systems for regulating a variable condition in response to the deviation during successive cycles of an effect caused by the variable condition as cyclically compared with a selected standard.

The invention is useful in the regulation of the tilting movement of a lip pouring vessel where the actual rate of pour from the vessel can be periodically compared with a standard to actuate the control and to thereby vary the vessel tilting movement to maintain the actual pouring rate substantially constant in conformity with the standard. A uniform pour rate is desirable in many processes, but is usually not obtained when a pouring vessel is tilted with a uniform angular motion. The variation in pour rate from such a vessel, when subjected to a uniform angular tilting motion, depends upon the internal shape of the vessel. Such vessels can be tilted at a varying angular rate according to a program control to attain a substantially constant pour rate. However, when the vessel is subjected to liquids of a type causing a change in the internal shape of the vessel, a program type of pouring control is inaccurate and generally unsatisfactory in maintaining a constant pour rate.

The erosive action of molten steel on most refractory lined vessels is well known and when pouring molten steel from a tilting vessel a program control is not capable of maintaining a constant pour rate from the vessel without the use of a manual, or automatic, tilting compensating means. While a program type of control may be used in some metal handling processes, it is generally unsatisfactory in a continuous casting process where uniformity is essential to quality and economy. A substantially constant pour rate is particularly important in a process for continuously casting steel to attain a high production rate and a satisfactory product.

In accordance with the present invention the cyclic deviation of a variable element is compared in terms of units of time with a standard of time. The time deviation comparison is utilized to regulate the variable element during each cycle and to anticipate the variation in the succeeding cycle. In the illustrative embodiment of the invention hereinafter described, the control system is utilized to regulate the tilting movements of a lip poured vessel arranged to deliver molten steel into the open upper end of a continuous casting mold. The steel casting is withdrawn from the lower end of the mold by a withdrawal mechanism which is operated in an intermittent cycle causing the casting to be subjected to an alternate "run" and "dwell" during each cycle. The regulation of the withdrawal mechanism is separate, in function, from the pour rate tilting control of the present invention. Since the withdrawal mechanism is operated on a fixed time basis and at a constant average lineal rate of casting withdrawal, a substantially constant volume of molten metal should be added to the mold during the standard time dwell time to maintain a coordinated relationship between the metal entering and leaving the

2

casting mold. The deviation of the actual "dwell" time in the casting withdrawal cycle, as compared with a standard time of casting "dwell" is utilized to actuate the control system and to regulate the tilting rate of the lip pour vessel.

The various features of novelty which characterize this invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which an embodiment of the invention has been illustrated and described.

In the drawings:

Fig. 1 is a side elevation of a portion of a continuous casting apparatus incorporating the control system of the present invention;

Fig. 2 is a wiring diagram of the control system utilized in the apparatus of Fig. 1, with the circuit shown in the conventional "dead board" condition;

Figs. 3-8 illustrate different contact positions in the control circuit during operation of the continuous casting unit shown in Fig. 1;

Fig. 9 illustrates the mechanical connection between portions of the control system shown in Fig. 2;

Fig. 10 is a graphical illustration of a typical sequence of control cycles in the operation of the continuous casting unit shown in Fig. 1; and

Figs. 11 to 14 diagrammatically illustrate successive steps in the operations of a part of the control system during a portion of the control sequence shown in Fig. 10.

The present invention is illustrated in the drawings as applied to a continuous casting unit of the general type disclosed and claimed in the co-pending application of I. Harter, Jr., Serial No. 103,901, filed July 9, 1949, now Patent No. 2,682,691. As shown, the casting apparatus includes metal pouring means arranged to deliver molten metal at a predetermined substantially uniform temperature into the upper end of a vertically arranged stationary liquid cooled casting mold. The molten metal is continuously cooled while within the mold to form an embryo casting having a rim or shell of solidified metal of increasing thickness. The embryo casting leaving the mold has a solidified shell of sufficient thickness and strength to be self-sustaining. The casting is withdrawn from the mold by a withdrawal mechanism which is operated in an intermittent cycle of run and dwell, in the manner described in said co-pending application. Beneath the withdrawal mechanism, the casting may be cut into lengths, coiled or otherwise handled as desired.

In an intermittent casting withdrawal operation the withdrawal mechanism is actuated in a cycle of alternate "run" and "dwell," with the "run" and "dwell" portions of each cycle regulated in accordance with measurements of time, measurements of the variation in molten metal level within the mold during each cycle, or by a combination of time measurements and distance variation. Regardless of the method by which the withdrawal mechanism is controlled during the intermittent cycle, the molten metal level within the mold will rise and fall. With a constant rate of molten metal delivery to the mold and a uniform cycle of intermittent withdrawal of the casting the molten metal level will rise and fall within predetermined levels. With such uniformity in the casting procedure, the production rate of casting can be at a maximum with the most efficient utilization of the mold cooling effect. However, it has proven difficult to satisfactorily regulate the pouring means to insure a constant molten metal pour rate to the casting mold. The control system of the present invention is utilized to regulate the variations in the angle of tilt of a lip pouring vessel to insure an accurate constant metal

pouring rate. This is accomplished by actuating the control mechanism in response to the deviation in time required to "raise" the molten metal level in the mold during the "dwell" portion of an intermittent withdrawal cycle in comparison with a norm of a selected time period. Thus, if the actual time required during the "dwell," during which the molten metal level rises within the mold to the predetermined upper limit, is greater than the selected time of the norm the pour rate is increased, and vice versa.

As shown in Fig. 1, the metal pouring means includes a vessel 10 arranged for lip pouring, and a tun dish 11 arranged to receive molten metal from the vessel and to deliver a substantially slag-free stream of metal to a selected position in the open upper end portion of a continuous casting mold assembly 12. The vessel 10 may be a melting furnace, or a holding and pouring ladle arranged to be charged with molten metal as delivered thereto by a transfer ladle. Advantageously the vessel 10 is heated, so that the molten metal poured therefrom is delivered to the mold at a substantially uniform temperature.

The vessel 10 is arranged for tilting movement about a transverse horizontal axis defined by trunnions 13 extending outwardly on opposite sides of an L-shaped frame 14 supporting the vessel. The trunnions are supported in trunnion bearings 15 each of which is mounted on a pedestal 16 and arranged for sliding movement in a horizontal direction normal to the axis of tilting movement. The transverse position of the vessel 10 relative to the tun dish 11 is regulated by means of gear motors (not shown) connected to the adjusting screws 17. The tilting movement of the vessel is obtained by any suitable method, such as the operation of a motor driven drum hoist 18. The hoist is connected to the vessel 10 by a cable 20 and a yoke 21 which is attached to the platform of the frame 14 supporting the vessel.

Beneath the mold 12, the casting formed therein is engaged by a set of pinch rolls 25 driven by a variable speed motor 26. The motor 26 is provided with a brake 27 in its connection with the pinch rolls 25 to regulate the deceleration rate of the withdrawal mechanism at the end of the casting "run" period. The casting leaving the mold 12 is subjected to the direct cooling effects of a water spray from a plurality of jets formed in the encircling manifold 30, and is restrained against transverse movement by guide shoes 31 or the like positioned intermediately in the space between the mold 12 and the pinch rolls 25.

In the arrangement shown in Figs. 1 and 2, the pinch roll motor control is arranged to be started at the end of the "dwell" period by the molten metal level rising to an upper position in the mold 12 to occlude the penetrating radiation of a molten metal level indicator assembly shown at 32. A suitable type of molten metal level indicator is disclosed and claimed in a co-pending application of I. Harter, Jr., Serial No. 73,643, filed January 29, 1949, now U. S. Patent No. 2,641,034. According to said application, a source of penetrating radiation, such as an X-ray tube, is provided within a shielded container 33, with a stream of penetrating rays therefrom directed through a shielded conduit 34 across the mold. At the opposite side of the mold an ionization chamber 35 receives any radiation passing through the mold. An electrical means measures the conductivity of the ionization chamber 35, so that a predetermined change in the conductivity thereof will indicate the presence of molten metal at the level of the indicator. Changes in the conductivity of the chamber are transmitted through the leads 36 to an amplifying circuit (not shown) and thence to a relay in a control box 37. The contacts of the relay are shown in Fig. 2, at B. Closing the contacts B in response to the operation of the level indicator completes a circuit to the controller 38 of the pinch roll motor 26 to start the operation of the

withdrawal or "run" of the intermittent cycle of casting withdrawal. The duration of pinch roll operation or the "run" period is regulated by the timer R. When the adjusted time period of the timer R has elapsed, the pinch rolls stop or operate at a reduced speed, and the resulting "dwell" period will continue until the level controller assembly 32 is actuated by the rise in the molten metal level within the mold to repeat the cycle of pinch roll operation. The pinch roll operating controls described are substantially the same as those disclosed and claimed in the Harter, Jr. application, Serial No. 103,901.

Any deviation in the elapsed time of the "dwell" in successive cycles of the intermittent withdrawal of the casting is indicative of a variation in the delivery rate of molten metal to the mold. The "dwell" period is defined as the period between stoppage of the pinch roll power supply in response to the action of the timer R and starting the pinch rolls in response to the action of the level controller assembly 32. As shown in Fig. 2, a timer D is arranged in the circuit so as to be started when the power supply to the pinch roll motor is cut off by the timer R. This is accomplished by a relay 1 which is energized by the operation of the pinch roll motor. When the pinch rolls are stopped, relay 1 is deenergized with contacts 1a and 1d closed, and 1b, 1c and 1e opened. This starts the timer D and energizes relay 2.

As shown in Fig. 2, the control system of the present invention includes four motors MR, VR, M-1 and M-2, where MR and VR drive two rheostats arranged in series in the speed control circuit of the motor driven hoist 18. VR designates a motor driving the vernier rheostat, while MR designates a motor driving the master rheostat. Motors M-1 and M-2 are essentially timers and are of the reversing self-starting synchronous type geared for an output speed of one revolution per minute. Each timer (M-1, M-2) and the master rheostat MR is provided with a direct connected cam and a pair of micro-switches as indicated in Fig. 9. The motors are connected in a wiring circuit actuated by the pinch roll motor control and the dwell timer D for operation in a sequence hereinafter described. The accuracy of the timer motors M-1 and M-2, and the rheostat motors is important in such a control circuit to prevent overtravel and "hunting." Ordinarily motors of the type described would have an appreciable "over run" due to the tremendous speed reduction from motor rotor to output shaft. To prevent such motor over run a small D. C. voltage is impressed on each motor when the A. C. voltage is removed. This D. C. voltage serves to make the motor stator into a magnet and the motor rotor is practically instantaneously stopped when the A. C. control power is disconnected.

During each dwell period the actual time of dwell is compared with the desired dwell time and the speed of the hoist motor is adjusted accordingly. In general, the circuit shown in Fig. 2 will adjust the position of the rheostat motor VR in substantially direct proportion to and accordance with the comparison of actual dwell time to the selected standard time of timer D. This is accomplished while the time comparison is being measured. In addition to this corrective effect, the vernier rheostat motor VR is correctively adjusted after the measurement of the time comparison to compensate for the rate of change of deviation at which the actual time measurements approach the standard "dwell" time.

As shown in Fig. 2, the control circuit includes a group of switches A, B, C and E, and a group of relays 1 to 10, inclusive, with the contacts of each relay indicated by the number of the relay and an identifying letter. In addition, suitable resistors and condensers are included in the circuit, where necessary. Switch A is closed to energize relay 9, and to initiate the operation of the control circuit in conjunction with the operation of the pinch rolls of the casting withdrawal mechanism. Switch B is actuated by the operation of the X-ray type of level con-

troller shown in Fig. 1. The contacts of this switch are actuated momentarily and actuate the pinch roll motor which continues in operation until the circuit is opened by opening the contacts MCR or the manual "stop" switch. Immediately following the closing contact of the switch B the pinch roll operation will lower the molten metal level within the mold, so that the level controller will again open the contacts of the switch B. The switch C is provided with two contact positions. When the switch is closed through contact C1 the control system utilizes the compensating feature characteristics of the invention, as hereinafter described, and when the switch is closed through contact C2 the compensating functions of the timer motors M-1 and M-2 are eliminated with the motorized elements returning to their set positions or "homing."

There are three possible systems of operating the circuit with the master rheostat (MR) either (1) homing, (2) non-homing, or (3) non-automatic. The selection of the proper method of operating the rheostat MR depends on the geometry of the pouring vessel 10 controlled by the circuit.

I. Homing: Where the controlling capacity of the vernier rheostat VR is insufficient to adequately correct the rate of pour the master rheostat MR may be made to increase the effect of the vernier steps by and in proportion to the square of the comparison of actual dwell time to the selected standard time of timer D. The rheostat MR will always vary from a common base setting, i. e., home.

II. Non-homing: Where the shape of the pouring vessel is such that the above arrangement of vernier and master rheostats is able to control the pouring rate of vessel 10 over a large percentage of the pouring operation, but is unable to cope with a marked increase in deviation, switch E may be opened to prevent the master rheostat from homing. This greatly magnifies the effect of the master rheostat movement because its change in setting is effective for almost full periods of withdrawal plus dwell instead of just two times the deviation. The squared relationship no longer holds under this condition because the change in speed is effective for an essentially constant period of time.

III. Non-automatic: Where the shape of the pouring vessel is such that the effect of the vernier rheostat, per unit of dwell deviation time is sufficient to adequately control the flow from the pouring vessel, the master rheostat is disconnected from its motor MR by means of a manually operated clutch (not shown).

The gearing between the vernier rheostat motor and the vernier rheostat is such as to give a corrective adjustment to the speed of the hoist motor. In order to choose the proper gearing for the vernier rheostat drive, the effect of various master rheostat positions together with the vernier rheostat effect must be ascertained by trial, and the proper combination is that which gives the hoist motor the desired rate of change for the geometry of the particular vessel in use.

It will be noted that relay coils 1 and 2 perform initiating functions for the remainder of the circuits and particularly control the relay coils 3 and 4. Relay coil 1 and clutch coil CCR can only be energized by the starting of the pinch rolls and deenergized by the stopping of the pinch rolls. Relay coil 2 and clutch coil CCD can only be energized through the contact 1a by the stopping of the pinch rolls, and can only be deenergized by the opening of contact MCD of timer D. In the case of a long dwell the contact arm (not shown) of timer D opens MCD and deenergizes coil 2. Since CCD is deenergized by the starting of the pinch rolls, contact arm of timer D does not permit MCD to reclose until contact (1a) has been opened by relay coil 1 being energized by the starting of the pinch rolls. Relay coils 3 and 4 can only be energized by the combined action of the starting of the pinch rolls and the end of desired dwell time but

the action is initiated by whichever of these two conditions occurs last. However, relay coil 3 being a latching type relay reverses its contact on energization and maintains its contacts in this reversed condition until reenergized by the action detailed above in the next subsequent cycle. On the other hand, relay coil 4 is deenergized and reverses its contacts when the pinch rolls stops at the end of the current run period.

Since there are only three possible variations of a dwell period i. e., shorter than, equal to, or longer than, the desired dwell time, there are then only three possible combinations of the sequence of operations of relay coils 1 and 2. These are as follows:

I. An actual dwell period shorter than desired dwell period where the pinch rolls start prior to the expiration of desired dwell time thus terminating the actual dwell time. However, timer D continues until MCD is opened at the termination of the desired dwell time. Relay coil 1 is energized opening its contacts 1a and 1d and closing its contacts 1b and 1e. Clutch coil (CCD) remains energized until main contact MCD is opened deenergizing relay coil 2, thus, opening its contacts 2a and 2c and closing its contacts 2b, 2d, and 2e. The time between these two operations, being the time between the actual and desired dwell time is the amount of time this dwell period deviates from the desired dwell period.

II. An actual dwell period substantially equal to the desired dwell period causes the deviation from the desired dwell time to be substantially zero, i. e., where the deviation time may be in terms of micro-seconds and thus the mechanical delay time of the circuit prevents the simultaneous energizing of relay coil 1 and deenergizing of relay coil 2 which would prevent the proper operation of relays 2 and 3.

III. An actual dwell period greater than the desired dwell period, where the desired dwell time expires before the starting of the pinch rolls ends the actual dwell time. Relay coil 2 is deenergized by contact MCD of timer D being opened by the contact arm of timer D, thus, opening 2a and 2c and closing contacts 2b, 2d, and 2e. At the start of the pinch rolls relay coil 1 is energized, opening its contact (1a) and thus deenergizing clutch coil CCD of timer D, as well as opening contact 1d and closing contacts 1b, 1c, and 1e.

It will be noted from the three possible variations of a dwell time outlined above that the relay coils 1 and 2 in their effect upon coils 3 and 4 direct and control the isolated A. C. power supplied to the motor driven cams and rheostats. The effect of different variations in the actual dwell time of the casting within the mold is illustrated in Figs. 2-8. Fig. 2 shows the conventional dead board position of the control system contacts. Fig. 3 shows the contact positions of the control during a dwell prior to the termination of either the actual or desired dwell time. Fig. 4 shows the contact positions during the dwell before the expiration of either the desired or actual dwell time, while the corrective time deviation recorded or stored on timer M2 maintains the limit switch LS6 closed. The limit switches LS1 to LS6, inclusive, are mechanically actuated by cams mounted on the shafts of motors M1, M2 and MR, as shown in Fig. 9. Fig. 5 shows the contact positions during a dwell when the desired time of dwell has elapsed, but the pinch rolls have not been started. Timer M2 retains a corrective time deviation with contact LS6 closed. Fig. 6 shows the contact positions of the control after the pinch rolls have been started which occurred after the expiration of the desired dwell time. Fig. 7 shows the contact positions of the control during operation of the pinch rolls, after completion of the "homing" of M2 and MR. Fig. 8 shows the contact positions of the control during a dwell period immediately following the run period shown on Fig. 7, with timer M2 ready to receive and store the deviation in actual dwell time from the desired dwell time or norm.

The following tabulation describes the contact positions and other operating conditions of the control circuit during the various possible deviations in the metal pouring rate of the mold.

Description of the control time conditions for the various columns of the table

Column No.:

- I. Enumeration of component coils, contacts, switches, timers, motor driven memory cams, motor driven rheostats, and limit switches. 10
- II. Condition of control board without any electrical power imposed, i. e., the conventional dead board drawing. See Fig. 2.
- III. Condition of control board after power is supplied to all lead terminals by master switches not shown and switches closed in the following order. A, E, and C to position 1. See Fig. 3. The control board is now in the condition of timing a dwell period i. e., at a time in the dwell period following the start of the "dwell" and before the expiration of either the desired dwell time as preset on timer D, or the actual dwell time as determined by the start of the pinch rolls through switch contact B in response to the occlusion of the X-ray beam. 25
- IV. The condition of the control board in a run period as a result of perfect dwell period, i. e., when the termination of the desired dwell period coincides with the termination of the actual dwell time. 30

- V. Condition of the control board immediately after actual dwell time has been terminated by the start of the pinch rolls and before the expiration of the desired dwell time. This is the first deviation of the control board from that shown in column III in response to the above time sequence of events which signals a dwell time shorter than the desired dwell time, indicating that the furnace was delivering metal at too high a rate.
- VI. Condition of the control board after the expiration of the desired dwell time, as preset by timer D, and subsequent to the termination of the actual dwell time, as determined by the starting of the pinch rolls in response to the occlusion of the X-ray beam. This is the second action of the control board in response to a short dwell signal.
- VII. Conditions of control board immediately after the expiration of the desired dwell time, as preset in timer D, but before the expiration of the actual dwell time. This is the first deviation of the control board from conditions of column III in response to the above signals indicating that the dwell period will be longer than desired which in turn indicates that the furnace delivery rate is too low.
- VIII. Conditions of the control board immediately after the expiration of the actual dwell time as terminated by the starting of the pinch rolls subsequent to the termination of the desired dwell time. This is the second action of the control board in response to a long dwell time.

I	II	III	IV	V	VI	VII	VIII
Timer R.....	Off.....	On.....	On.....	On.....	On.....	On.....	On.....
Timer D.....	Off.....	On.....	On.....	On.....	On.....	On.....	On.....
A.....	Open.....	Closed.....	Closed.....	Closed.....	Closed.....	Closed.....	Closed.....
B.....	Open.....	Open.....	Closed.....	Closed.....	Closed.....	Open.....	Closed.....
C.....	Open.....	Closed.....	Closed.....	Closed.....	Closed.....	Closed.....	Closed.....
E.....	Open.....	Closed.....	Closed.....	Closed.....	Closed.....	Closed.....	Closed.....
1.....	DE.....	DE.....	EN.....	EN.....	EN.....	DE.....	EN.....
1a.....	Closed.....	Closed.....	Open.....	Open.....	Open.....	Closed.....	Open.....
1b.....	Open.....	Open.....	Closed.....	Closed.....	Closed.....	Open.....	Closed.....
1c.....	Open.....	Open.....	Closed.....	Closed.....	Closed.....	Open.....	Closed.....
1d.....	Closed.....	Closed.....	Open.....	Open.....	Open.....	Closed.....	Open.....
1e.....	Open.....	Open.....	Closed.....	Closed.....	Closed.....	Open.....	Closed.....
CCR.....	DE.....	DE.....	EN.....	EN.....	EN.....	DE.....	EN.....
CCD.....	DE.....	EN.....	DE.....	EN.....	EN.....	DE.....	DE.....
MCR.....	Closed.....	Closed.....	Closed.....	Closed.....	Closed.....	Closed.....	Closed.....
MCD.....	Closed.....	Closed.....	Closed.....	Closed.....	Closed.....	Closed.....	Closed.....
2.....	DE.....	EN.....	DE.....	EN.....	(Op-Cl)	Open.....	Closed.....
2a.....	Open.....	Closed.....	Open.....	Closed.....	DE.....	DE.....	DE.....
2b.....	Closed.....	Open.....	Closed.....	Open.....	Open.....	Open.....	Open.....
2c.....	Open.....	Closed.....	Open.....	Closed.....	Closed.....	Closed.....	Closed.....
2d.....	Closed.....	Open.....	Closed.....	Open.....	Open.....	Open.....	Open.....
2e.....	Closed.....	Open.....	Closed.....	Open.....	Closed.....	Closed.....	Closed.....
3*.....	DE.....	DE.....	EN.....	DE.....	Closed.....	Closed.....	Closed.....
3a*.....	Closed.....	Closed.....	Open.....	DE.....	EN.....	DE.....	EN.....
3b*.....	Open.....	Open.....	Closed.....	Open.....	Open.....	Closed.....	Open.....
3c*.....	Open.....	Open.....	Closed.....	Open.....	Closed.....	Open.....	Closed.....
3d*.....	Closed.....	Closed.....	Open.....	Open.....	Closed.....	Open.....	Closed.....
3e*.....	Closed.....	Closed.....	Open.....	Closed.....	Open.....	Closed.....	Open.....
3f*.....	Open.....	Open.....	Closed.....	Open.....	Open.....	Closed.....	Open.....
3g*.....	Closed.....	Closed.....	Open.....	Open.....	Closed.....	Open.....	Closed.....
3h*.....	Open.....	Open.....	Closed.....	Open.....	Open.....	Closed.....	Open.....
3j*.....	Closed.....	Closed.....	Open.....	Open.....	Closed.....	Open.....	Closed.....
3k*.....	Open.....	Open.....	Closed.....	Open.....	Open.....	Closed.....	Open.....
4.....	DE.....	DE.....	EN.....	DE.....	Closed.....	Open.....	Closed.....
4a.....	Open.....	Open.....	Closed.....	Open.....	EN.....	DE.....	EN.....
4b.....	Open.....	Open.....	Closed.....	Open.....	Closed.....	Open.....	Closed.....
4c.....	Closed.....	Closed.....	Open.....	Closed.....	Closed.....	Open.....	Closed.....
4d.....	Closed.....	Closed.....	Open.....	Closed.....	Open.....	Closed.....	Open.....
4e.....	Closed.....	Closed.....	Open.....	Closed.....	Open.....	Closed.....	Open.....
4f.....	Closed.....	Closed.....	Open.....	Closed.....	Open.....	Closed.....	Open.....
4g.....	Closed.....	Closed.....	Open.....	Closed.....	Open.....	Closed.....	Open.....
4h.....	Closed.....	Closed.....	Open.....	Closed.....	Open.....	Closed.....	Open.....
5.....	DE.....	DE.....	DE.....	EN.....	Open.....	Closed.....	Open.....
5a.....	Closed.....	Closed.....	Closed.....	Open.....	EN.....	EN.....	EN.....
6.....	DE.....	DE.....	DE.....	EN.....	Open.....	Open.....	Open.....
6a.....	Closed.....	Closed.....	Closed.....	Open.....	DE.....	EN.....	DE.....
7.....	DE.....	DE.....	DE.....	EN.....	Closed.....	Open.....	Closed.....
7a.....	Closed.....	Closed.....	Closed.....	Open.....	EN.....	EN.....	EN.....
8.....	DE.....	DE.....	DE.....	EN.....	Open.....	Open.....	Open.....
8a.....	Closed.....	Closed.....	Closed.....	Open.....	EN.....	EN.....	EN.....
9.....	DE.....	EN.....	EN.....	EN.....	Open.....	Open.....	Open.....
9a.....	Open.....	Closed.....	Closed.....	Closed.....	EN.....	EN.....	EN.....
9b.....	Open.....	Closed.....	Closed.....	Closed.....	Closed.....	Closed.....	Closed.....
10 and all its contacts. (See note.)	Open.....	Closed.....	Closed.....	Closed.....	Closed.....	Closed.....	Closed.....
VR.....				CCW.....	CCW.....	CW.....	CCW.....
MR.....				CCW.....	CW.....	CW.....	CCW.....
M-1.....				CCW.....	CW.....	CW.....	CCW.....
M-2.....				CW.....	CCW.....	CCW.....	CCW.....

Footnotes on following page

I	II	III	IV	V	VI	VII	VIII
LS1.....	Open....	Open....	Open....	Open....	Open....	Closed..	Open....
LS2.....	Open....	Open....	Open....	Closed..	Open....	Open....	Open....
LS3.....	Open....	Open....	Open....	Closed..	Closed..	Open....	Open....
LS4.....	Open....	Open....	Open....	Open....	Open....	Closed..	Closed..
LS5.....	Open....	Open....	Open....	Open....	Open....	Closed..	Open....
LS6.....	Open....	Open....	Open....	Closed..	Open....	Open....	Open....

DE—Deenergized.

EN—Energized.

(C)—Contact C1.

NOTE.—Relay 3 marked (**) is a latching or sequence relay whose coil is energized at the start of pinch rolls or end of actual dwell time whichever occurs last. Energizing of its coil reverses all contacts and coils marked (*). Latching mechanism of this relay is actuated by its own coil.

(Open-Closed) indicates that the contacts MCR and MCD have momentarily opened immediately prior to the conditions set forth in the rest of the column.

Coil 10 and all its contacts constitute a system for clearing of any false recordation or storage of pour rate deviation which may have been put in the board due to any temporary physical obstructions such as slag dams, etc., occurring in the metal pouring notches of the pouring vessels, and is actuated by throwing switch "C" into C2 position. This energizes coil 10 and reverses all 10 contacts from that shown on dead board drawing. This action cancels the stored or recorded deviation in the control and "homes" both cams on M1 and M2. Closing switch "C" to position C1 after clearing the obstruction places the board back in operating condition.

Limit switches LS1 to LS6, as shown in this table, are held closed or allowed to open by the cams, hence, the LS positions shown in the table are a direct result of the CW or CCW rotations indicated on the appropriate cams in the column above.

The storing of a deviation or time error in M1 or M2 causes the closing of the appropriate limit switch depending on whether the particular time error is longer than desired, causing a CW rotation of the cam; or a dwell time shorter than desired, causing a CCW rotation of the cam. However, the returning of the stored information to the control in the next cycle is completed with the power to the cam motor flowing through the appropriately closed limit switch to run the cam in the appropriate direction from that used when the deviation was stored.

The assumption was made that the control was starting without any recorded deviation of dwell time, or in the zero-zero position of cams of timers M1 or M2 for the following columns: III, IV, V, and VII.

A typical example of the operation of the described control systems, as applied to the regulation of molten metal delivery rate to a continuous casting unit of the type described is shown in Fig. 10. Nine cycles are shown of a continuous casting process utilizing an intermittent cyclic casting withdrawal arrangement of the type disclosed and claimed in the co-pending application of I. Harter, Jr., Serial No. 103,901. In the graph the "run" time of casting withdrawal is set by the timer R (Fig. 2) at 10 seconds, while the desired dwell time, which is set on the timer D, is also 10 seconds. The relationship between run and dwell can, of course, be of any desired value as pointed out in the Harter, Jr., application. The actual "dwell" time is indicated by the solid line superimposed on the desired "dwell" time which is indicated by the straight dotted line. The movements of the master rheostat MR, vernier rheostat VR and of each of the timers M-1 and M-2 are shown separately. It will be noted that the actual dwell time is long during the first of the cycles, with the control quickly bringing the actual and desired dwell times into substantial agreement. It will also be noted that the timers M-1 and M-2 serve alternately to store the deviation in time of the actual dwell compared with the desired dwell, starting with M-2 in cycle 2.

Figs. 11-14, inclusive, diagrammatically illustrate the actual position of the timers M1 and M2, as well as rheostat motors MR and VR, at the end of the third, fourth, fifth and sixth cycles respectively, shown in Fig. 10.

In the operation of a continuous casting unit of the type described, a "dummy" bottom is inserted in the lower portion of the fluid cooled mold 12, and molten steel or other metal is delivered by the furnace 10, through the tun dish into the upper end of the mold. The use of a "dummy" in the initial operations of a continuous casting unit is well known in the art and is not illustrated in this application. As an embryo casting is formed, and the molten metal level rises to its upper operating position in the mold, the "dummy," with the casting attached thereto, is withdrawn downwardly by the pinch rolls 25. The operation of the pinch rolls is regulated manually by means of the "start" and "stop" contacts shown in the pinch roll motor control circuit illustrated in Fig. 2. With the master control rheostat set for the approximately correct tilting rate for the furnace 10, the control of the present invention is started by closing switches A and E, and setting switch C at position C1. This is done during the "run" period. The control

circuit condition is illustrated in Fig. 3, when no time deviation is stored on either M1 or M2 and the timer D is in operation.

In the example of operations shown in Fig. 10, the pour rate has been assumed to be too slow, i. e. the "dwell" time is 14 seconds or 4 seconds beyond the desired 10 seconds "dwell." This time deviation has caused a short "pulse" of an increased pouring rate to be effected by the master rheostat MR, and an increase in the pour rate by reason of a change in the position of the vernier rheostat VR. Normally M1 would "home," carrying VR with it, from a position determined by the difference between the preceding stored error and the present error. Since, under the starting conditions of this example, no time deviation has been stored on M1 from the previous cycle, its effect is to double the correction due to error because it "homes" from the present error position and carries VR with it. However, a time deviation of 4 seconds duration from the first cycle is retained on the timer for use in the succeeding cycle. The second cycle is 2 seconds longer than the norm, i. e. a "dwell" of 12 seconds, while the third cycle is 1.5 seconds longer than the norm, with an actual "dwell" period of 11.5 seconds.

Fig. 11 illustrates the movement of the control elements M1, M2, VR and MR during the third cycle shown on Fig. 10. At the beginning of this cycle, timer M1 retains a stored time deviation of 2 seconds from the preceding cycle (cycle #2 of Fig. 10). During the "dwell" period prior to the expiration of the period timed by timer D, and before the operation of the run cycle which terminates the actual dwell period, the control circuit will be in the condition shown by Fig. 4. At the end of the desired 10 second dwell period, as determined by the setting of the timer D, the control circuit will assume the condition shown in Fig. 5. As shown in Fig. 11, the termination of the 10 second desired dwell period starts timer M1, which runs for the duration of the difference between the desired and actual dwell periods, namely 1.5 seconds. Coincidentally with the movement of M1, the master rheostat MR moves from 38 to 39.5 and the vernier rheostat moves from 38 to 39.5. The timer M2 started with M1, but in the opposite direction, and when the pinch rolls started still retained .5 second representing the excess in time deviation between cycles #2 and 3. With the starting of the pinch rolls, M1 stops, retaining the deviation in time of 1.5 from cycle # 3 for corrective use in the succeeding cycle, and the master rheostat MR returns to its original position. However,

11

with .5 second retained on M2, the timer M2 in returning to zero causes the vernier VR to move from 39.5 to 39. The condition of the control circuit immediately after the starting of the pinch rolls in cycle 3 is shown in Fig. 6. Starting the pinch rolls causes the energization of relays 3 and 4. Relay 3 is a latching or reversing type of relay and its energization secures the contacts in a reversed condition so that the direction of rotation of the timers M1 and M2 is reversed in each succeeding cycle of casting withdrawal and "dwell." The condition of the control circuit during the "run" period of casting withdrawal, and after M2 and MR have returned to zero and "home" position, respectively, is shown in Fig. 7. The condition of the control circuit at the beginning of the dwell period is shown in Fig. 8. It will be noted that the limit switch LS4 is closed in this figure, and corresponds with the stored time deviation on timer M1. The circuit showing on this figure will be substantially duplicated during the run portion of each cycle except for the contacts of reversing coil 3 and the limit switches LS3, LS4, LS5, and LS6.

Fig. 12 shows the movement of the timer and rheostat motor during cycle 4 of Fig. 10 where the actual dwell of the casting within the mold was 10.5 seconds. At the end of the desired 10 second dwell, timer M2 runs for a time deviation of plus .5 second, with VR moving from 39 to 39.5. Since timer M1 started with M2, but in the opposite direction of rotation, M1 will still retain a time deviation of plus 1.0 second when the pinch rolls start. Thus, when the pinch rolls start, the vernier will move from 39.5 to 38.5 with M1 returning to zero. The master rheostat also moved with M2 from 38 to 38.5 and returned to "home," or its base setting, when the pinch rolls started.

Fig. 13 illustrates the movement of the timers M1 and M2, and the rheostats VR and MR during the fifth cycle shown on Fig. 10. In this cycle the actual "dwell" time was 9.5 seconds or .5 less than the desired "dwell" time. At the start of the pinch rolls timer M1 moves from zero to minus .5, while at the same time the vernier and master rheostats move from 38.5 to 38 and from 38 to 37.5, respectively. M2 also moves from plus .5 to plus 1.0. At the end of the desired dwell time, M2 returns to zero plus 1.0 and the vernier rheostat VR moves from 38 to 37. Since an actual dwell time less than the desired dwell time indicates the delivery rate of metal to the casting mold is somewhat excessive, it is desirable to reduce the metal pour rate. This has been done by the controls, as shown in Figs. 10 and 13.

The operation of the timer motors and rheostats during the sixth cycle of Fig. 10 is shown in Fig. 14. During this cycle the actual dwell time was 9.75 seconds. At the start of the pinch rolls M2 moves from zero to minus .25, with the vernier and master rheostats moving from 37 to 36.75 and from 38 to 37.75, respectively. The master rheostat MR returns to its base position at 38, when the desired dwell time of 10 seconds has elapsed. The timer M1 starts with M2, but in the opposite direction, and since a time deviation of .5 second had been retained on M1 from cycle 5, the vernier rheostat is moved .25 second back to position 37 after the desired dwell time has elapsed.

In the description of cycle 3, shown on Figs. 10 and 11, the "dwell" time was 1.5 sec. "long," indicating the need for an increase in the pouring rate from the vessel 10. This increase is obtained by an advance in both the vernier and master rheostats during the measurement of the deviation. However, since the stored deviation from the preceding cycle was longer than the deviation measured in cycle 3, i. e. 2.0 seconds and 1.5 seconds respectively, the vernier rheostat was moved to a lesser value immediately after the measurement of the deviation in cycle 3. Thus, even though the cyclic measurement of the deviation indicates the need for a higher pouring rate to the casting mold, the net pouring rate

12

is less than that of the preceding cycle. This is due to the anticipatory feature of the control, which indicates that the actual pouring rate is approaching the proper pouring rate so that somewhat less correction than that proportioned to deviation is required and is reduced accordingly. It will further be noted the master rheostat motor is moved to a new position corresponding to the deviation, and in the proper deviation tending to compensate for the measurement of the time deviation and then returns to zero. The length of time required for this departure and return is two times the deviation time. Consequently, the contribution of this control being a product of speed times time is proportional to the square of the deviation. The master rheostat motor can be geared to the rheostat to attain any desired effect in the actual change in position of the rheostat. In addition, the rheostat may be constructed to increase or decrease the effect thereof on the motor driven hoist 18 in accordance with any function of the actual change in the position of the rheostat arm. While only two rheostats have been shown for the control of the motor driven hoist 18, it will be understood additional motor driven rheostats can be utilized. For example, a pair of vernier rheostats may be used, having different effects upon the speed of the motor driven hoist for equal angular changes in the rheostat arm positions. One of such rheostats could be driven during the measurement of the deviation in each cycle while the other rheostat could be driven after the measurement of the time deviation by the anticipatory effect of the successive cyclic deviation measurements.

From the foregoing description it will be noted the tilting rate of the furnace 10 is regulated to cause a substantially uniform rate of molten metal delivery to the mold assembly 12 of a continuous casting unit. This is accomplished by utilizing the deviation in the time required to raise the molten metal in the mold to a predetermined level, as compared with a standard time. In the control system the timers M1 and M2 operate in opposite directions in each cycle, and both are reversed in their direction of movement in each successive cycle of casting "run" and "dwell." In addition, each timer alternately stores the deviation in time between the actual and desired duration of casting "dwell" in the mold for each cycle of casting withdrawal. The timers are activated by the completion of the timed, desired "dwell" and by the actual rise in molten metal to a predetermined level as determined by a level control.

If the dwell timer activates the control first, that is indicative of a condition wherein the molten metal pour rate is slow and the control will increase the tilting rate of the furnace by forward movement of both the master rheostat MR and the vernier rheostat VR. This movement of M1, M2, VR, and MR continues until the pinch rolls are started by the level control to withdraw the casting from the mold at a rate in excess of the molten metal pour rate. This terminates the "dwell" period of the casting cycle, and one of the timers M1 or M2 will stop to retain the time deviation in the present cycle for the succeeding cycle. The other timer M1 or M2 will return to zero, with the time necessary for its return dependent upon the amount and direction of the time deviation stored thereon from the preceding cycle added to or subtracted from the time deviation of the present cycle. During the time the timer M1 or M2, as the case may be, is returning to zero, the vernier rheostat VR will also be in corresponding movement. When the movement of the vernier rheostat has ceased, VR will remain in its position until changed during the next succeeding cycle. At the end of the time deviation in the "dwell" period the master rheostat returns to its previous setting.

While in accordance with the provisions of the statutes we have illustrated and described herein the best form of the invention now known to us, those skilled in the

art will understand that changes may be made in the form of the apparatus disclosed without departing from the spirit of the invention covered by our claims, and that certain features of our invention may sometimes be used to advantage without a corresponding use of other features.

What is claimed is:

1. The method of regulating a variable quantity in response to the deviation of an effect of said variable from a selected standard effect which comprises the steps of cyclically measuring the deviation of said effect from said standard, correctively adjusting said variable during and in accordance with the measurement of the deviation of said effect and storing said deviation for the adjustment of the succeeding cyclic measurement of the deviation of said variable effect, and continuing the corrective adjustment of said variable after the measurement of the deviation as influenced by the stored deviation of the preceding cycle of deviation measurement.

2. The method of regulating a variable quantity in accordance with the deviation of an effect of said variable from a selected standard effect which comprises the steps of cyclically measuring the deviation of said effect from said standard, correctively adjusting said variable in accordance with said deviation measurement including, a first adjustment in direct proportion to the deviation, a second adjustment in proportion to the square of the deviation, and a third adjustment proportional to the rate of change of deviation as determined by the difference between successive measurements of the deviation.

3. The method of regulating the flow rate from a vessel in response to the deviation of the actual flow rate from a selected standard flow rate which comprises the steps of cyclically measuring the deviation of said actual flow rate from said standard rate in temporal units, correctively adjusting the actual flow rate during and in accordance with the measurement of the deviation of said actual rate from the standard rate, storing said deviation in terms of temporal units for the succeeding cyclic measurement of the deviation of said actual flow rate, and continuing the corrective adjustment of said actual flow rate after the measurement of the deviation of said flow rate in accordance with the measurement of said deviation as influenced by the stored deviation of the preceding cycle of deviation measurement.

4. The method of regulating the flow rate from a pouring vessel in response to the deviation of the actual flow rate from said vessel in comparison with a selected standard flow rate which comprises the steps of cyclically measuring the deviation of said actual flow rate from said standard rate in units of time, correctively adjusting said variable in accordance with said deviation measurement including a first corrective adjustment proportional to and performed during the measurement of the deviation of said actual rate from the standard rate, a second corrective adjustment proportional to a mathematical function of the deviation and performed during the measurement of said deviation, storing said deviation in terms of units of time for the succeeding cyclic measurement of the deviation of said variable effect, and a third corrective adjustment of the actual flow rate performed after the measurement of the deviation with the measurement of said deviation as modified by the stored deviation of the preceding cycle of deviation measurement.

5. The method of regulating the pour rate from a tilting vessel in response to the deviation of the actual rate of pour from a selected standard rate which comprises the steps of cyclically measuring the deviation of said actual rate of pour from said standard rate in displacement units per unit of time, correctively adjusting the tilt of said vessel during and in accordance with the measurement

of the deviation of said actual rate from the standard rate, storing said deviation in terms of displacement units per unit of time for the succeeding cyclic measurement of the deviation of said actual pour rate, and continuing the corrective adjustment of said tilting vessel after the measurement of the deviation of said pour rate in accordance with the measurement of said deviation as influenced by the stored deviation of the preceding cycle of deviation measurement.

6. The method of regulating the pour rate from a tilting vessel in response to the deviation of the actual rate of pour from a selected standard rate which comprises the steps of cyclically raising and lowering the molten metal level between upper and lower level limits within a casting zone, measuring the deviation in duration of the actual rate of metal rise from a standard rate of molten metal rise, correctively adjusting the tilting rate of said vessel during and in accordance with the measurement of the deviation of said actual rate from the standard rate of molten metal rise, storing said deviation for the succeeding cyclic measurement of the deviation of said actual rate of rise, and continuing the corrective adjustment of said tilting vessel after the measurement of the deviation of said rate of rise in accordance with the measurement of said deviation as influenced by the stored deviation of the preceding cycle of deviation measurement.

7. The method of regulating the tilting rate of a pouring vessel which comprises selecting a standard time for pouring a volume of molten metal from said vessel, cyclically measuring the deviation in displacement units between the actual pouring of said volume of molten metal from the pouring vessel and said standard time of pouring, adjusting the tilting rate of change of said pouring vessel in magnitude and direction in response to and during the measurement of said deviation, storing said deviation for the next succeeding cyclic regulation of the tilting rate of change of said pouring vessel, and continuing the adjustment of the tilting rate of change of said pouring vessel after the measurement of said deviation in response to the deviation measured in the same cycle as modified by the deviation stored in the preceding cycle of deviation measurement.

8. The method of continuously casting ferrous alloys which comprises continuously pouring molten steel from a tilting vessel into a casting zone, withdrawing the casting from the casting zone in an intermittent cycle of "run" and "dwell," and automatically regulating the rate of change in the tilting rate of said pouring vessel in response to the deviation in successive cycles of time between the actual pouring of a volume of said molten steel into said casting zone in each cycle and a desired standard of time to pour the said volume of molten steel in the same cycle of casting dwell, including measuring the magnitude and direction of said deviation in each cycle and regulating said change in tilting rate in conformity with said deviation measurement.

9. Apparatus for regulating a variable quantity in response to the deviation of an actual effect of said variable from a selected standard effect which comprises, means for cyclically measuring the deviation between said actual effect and said standard effect, means for adjusting said variable during and in accordance with the cyclic measurement of the deviation, and a pair of timers each alternately operable in successive cycles of deviation measurement to store the deviation in units of time in each cycle of measurement of said deviation, the timer retaining a stored deviation from a preceding cycle arranged to correctively adjust said variable after the termination of the measurement of the deviation of said effect in one cycle according to the measurement of said deviation in that cycle as modified by the stored deviation of the preceding cycle of deviation measurement.

10. Apparatus for regulating a power actuator posi-

15

tioning a variable in response to the deviation of an actual effect of said variable from a selected standard effect which comprises means for cyclically measuring the deviation of said actual effect from said standard effect, means for adjusting the power actuator positioning said variable during and in accordance with the cyclic measurement of the deviation of said effect, and a pair of timers each alternately operable in successive cycles of deviation measurement to store the deviation in each cycle of measurement of said deviation, the timer retaining a stored deviation from a preceding cycle arranged to correctively adjust the power actuator to position said variable after the measurement of the deviation of said effect in one cycle according to the measurement of said deviation in that cycle as influenced by the stored deviation of the preceding cycle of deviation measurement.

11. Apparatus for regulating the speed of a motor driving a variable in response to the deviation of an actual effect of said variable from a selected standard effect which comprises means for cyclically measuring the temporal deviation of said actual effect from said standard effect, a motor driven rheostat for adjusting the speed of the motor driving said variable during and in accordance with the cyclic measurement of the deviation of said effect, and a pair of timers each alternately operable in successive cycles of deviation measurement to store the temporal deviation in each cycle of measurement of said deviation, the timer retaining a stored deviation from a preceding cycle arranged to correctively adjust the speed of the motor driving said variable through said rheostat after the measurement of the deviation of said effect in one cycle according to the measurement of said deviation in that cycle as influenced by the stored deviation of the preceding cycle of deviation measurement.

12. Apparatus for regulating the speed of a motor driving a variable in response to the deviation of an actual effect of said variable from a selected standard effect which comprises means for cyclically measuring the deviation of said actual effect from said standard effect in displacement units, a motor driven master rheostat and a motor driven vernier rheostat connected in parallel in the speed control circuit of the motor driving said variable during and in accordance with the cyclic measurement of the deviation, means returning said master rheostat to its preset position at the end of each deviation measurement, and a pair of timers each alternately operable in successive cycles of deviation measurement to store the deviation in displacement units in each cycle of measurement of said deviation, the timer retaining a stored deviation from the preceding cycle arranged to correctively adjust the vernier rheostat after the measurement of the deviation of said effect in one cycle according to the measurement of said deviation in that cycle as influenced by the stored deviation of the preceding cycle of deviation measurement.

13. Continuous casting apparatus including an open ended casting mold, a pouring vessel arranged to deliver molten metal to said mold, a casting withdrawal mechanism, means for cyclically measuring the difference between the actual and a standard rate of pour to said mold, and a control system operative in response to the present and the immediately preceding cyclic difference between the actual and desired pour rates of molten metal to adjust the rate of pour from said vessel to maintain the metal pouring rate to said mold substantially in accordance with said standard rate of pour.

14. Continuous casting apparatus including an open ended casting mold, a pouring vessel arranged to deliver molten metal to said mold, a casting withdrawal mechanism, means for cyclically measuring the temporal deviation between the actual and a standard rate of pour to said mold, and a control system operative in response to the temporal present and immediately preceding cycle

16

deviation between the actual and desired pour rates of molten metal to adjust the rate of pour from said vessel to maintain the metal pouring rate to said mold substantially in accordance with said standard rate of pour.

15. Continuous casting apparatus including an open ended casting mold, a pouring vessel arranged to deliver molten metal to said mold, a casting withdrawal mechanism, means including a variable speed drive connected with said withdrawal mechanism for changing the speed of said casting withdrawal mechanism and causing a cyclic change in the molten metal level within said mold between upper and lower level limits, means for measuring the difference between the actual rate of molten metal delivery to said mold and a standard rate of delivery comprising a timer arranged to indicate a standard time of molten metal rise between said lower and upper mold level limits, a level indicator positioned at the mold upper molten metal level limit arranged to indicate the termination of the actual molten metal rise in said mold, and a control system operative in response to the difference in time between the termination of the timed period of said timer and the indication of the molten metal rise to said upper level limit whereby the pouring rate from said pouring vessel is controlled to maintain the metal pouring rate to said mold substantially uniform.

16. Continuous casting apparatus including an open ended casting mold, a pouring vessel arranged to deliver molten metal to said mold, a casting withdrawal mechanism, means including a variable speed drive connected with said withdrawal mechanism for changing the speed of said casting withdrawal mechanism and causing a cyclic change in the molten metal level within said mold between upper and lower level limits by a cyclic operation of said withdrawal mechanism, means for regulating the tilting rate of said vessel to maintain a substantially uniform rate of molten metal delivery to said mold comprising a timer arranged to indicate a desired time of molten metal rise between said lower and upper mold level limits, a level indicator positioned at the mold upper molten metal level limit and arranged to indicate the actual rise of molten metal in said mold to said upper level, and a control system operative in response to the difference in time between the termination of the timed period of said timer and the indication of the molten metal rise to said upper level limit to adjust the pouring rate of said vessel to said mold.

17. In continuous casting apparatus, the combination including a fluid cooled vertically arranged molding tube open at both ends, a motor driven tilting vessel arranged to pour molten metal into the upper end of said molding tube, a casting withdrawal mechanism, means for regulating the operation of said withdrawal mechanism to cause a cyclic change in the molten metal level within said mold including a timer arranged to operate said withdrawal mechanism at a casting withdrawal rate in excess of said molten metal pour rate for a set period of time, a level controller arranged to start said timer and withdrawal mechanism when the molten metal level reaches an upper position in said mold, a second timer arranged to start with the rise in metal level from the lower level in said mold, and means for changing the tilting rate of said tilting vessel in response to the difference in time between the end of the set time of said second timer and the start of said casting withdrawal mechanism.

18. In continuous casting apparatus, the combination including a fluid cooled vertically arranged molding tube open at both ends, a motor driven tilting vessel arranged to pour molten metal into the upper end of said molding tube, a casting withdrawal mechanism, means for regulating the operation of said withdrawal mechanism to cause a cyclic change in the molten metal level within said mold including a timer arranged to operate said withdrawal mechanism at a casting withdrawal rate in excess of said molten metal pour rate for a set period of time, a level controller arranged to start said timer and withdrawal

17

mechanism when the molten metal level reaches an upper position in said mold, a second timer arranged to start with the rise in metal level from the lower level in said mold, and means for changing the tilting rate of said tilting vessel in response to the difference in time between the end of the set time of said second timer and the start of said casting withdrawal mechanism comprising a pair of motor driven rheostats connected in parallel in said tilting vessel motor circuit, a pair of control timers arranged to operate in opposite directions, separate relays energized by the termination of the timed period of said second timer and by the starting of said withdrawal system, the energization of either relay starting said control timers and said rheostats with the energization of the other relay stopping one control timer, and a reversing relay arranged to reverse the direction of rotation of said timers for each cycle of withdrawal mechanism operation.

19. In continuous casting apparatus, the combination including a fluid cooled vertically arranged molding tube open at both ends, a motor driven tilting vessel arranged to pour molten metal into the upper end of said molding tube, a casting withdrawal mechanism, means for regulating the operation of said withdrawal mechanism to cause a cyclic change in the molten metal level within said mold including a timer arranged to operate said withdrawal mechanism at a casting withdrawal rate in excess of said molten metal pour rate for a set period of time and a level controller arranged to start said timer and withdrawal mechanism when the molten metal level reaches

18

an upper position in said mold, a second timer arranged to start with the rise in metal level from the lower level in said mold, and means for changing the tilting rate of said tilting vessel in response to the difference in time between the end of the set time of said second timer and the start of said casting withdrawal mechanism comprising a pair of motor driven rheostats connected in parallel in said tilting vessel motor circuit, a pair of control timers arranged to operate in opposite directions, a control circuit interconnecting said rheostats and control timers actuated by said level controller and said second timer to energize said control timers and rheostats, a reversing relay arranged to reverse the direction of operation of said control timers in each cycle of control operation, and means for imposing direct current power on each of said control timers upon an interruption in the supply of alternating current to each.

References Cited in the file of this patent

UNITED STATES PATENTS

1,503,479	Coats	Aug. 5, 1924
2,231,569	Dickey	Feb. 11, 1941
2,246,907	Webster	June 24, 1941
2,276,096	Ryder	Mar. 10, 1942
2,473,863	Claybourn	June 21, 1949
2,501,681	Kirkpatrick	Mar. 28, 1950
2,586,713	Ratcliffe et al.	Feb. 19, 1952

FOREIGN PATENTS

598,385	Great Britain	Feb. 17, 1948
---------	---------------	---------------