

Oct. 22, 1963

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3,107,820

ANTICIPATORY DEVICE FOR FILLING HOPPERS

Filed Aug. 31, 1961

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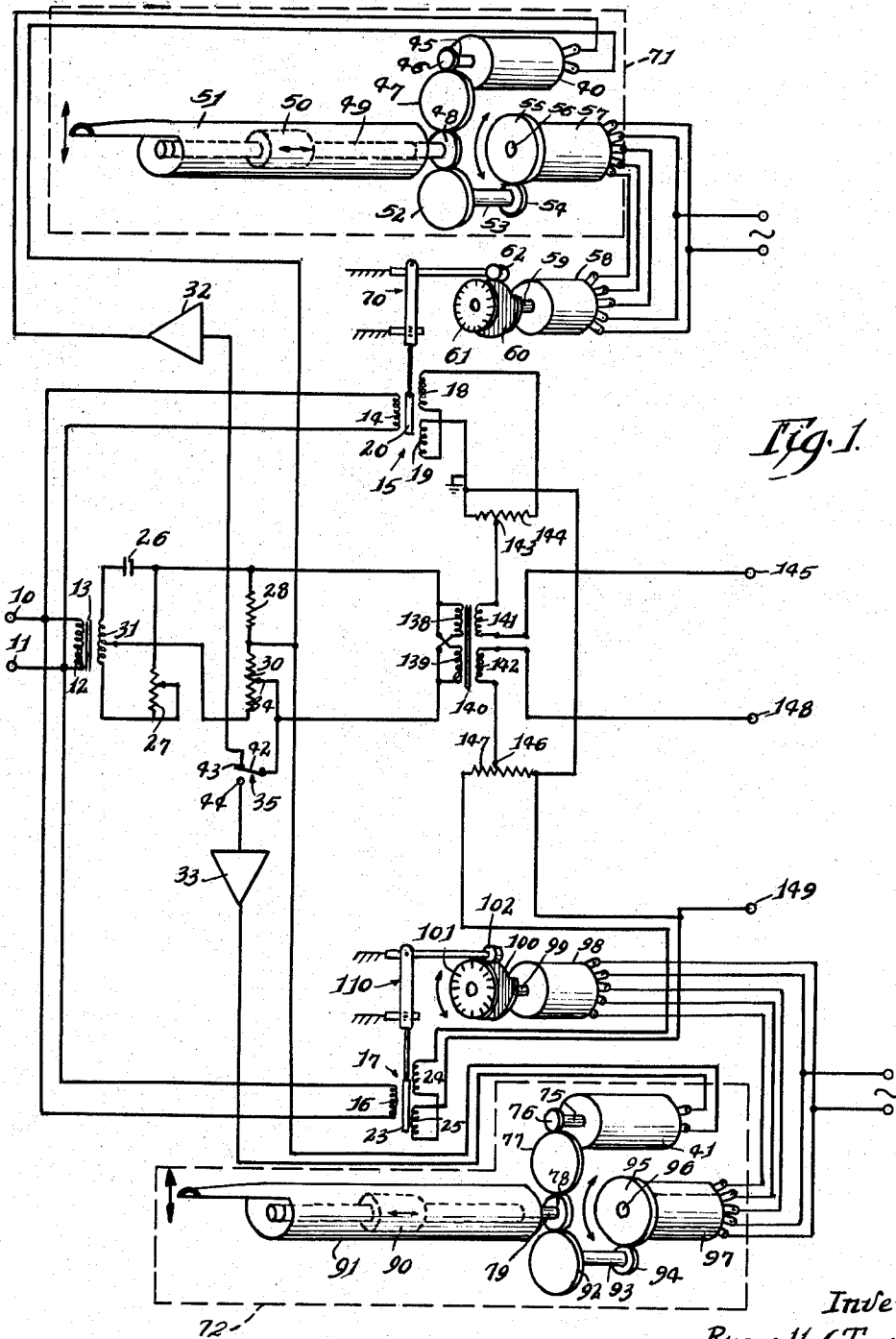


Fig. 1.

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Oct. 22, 1963

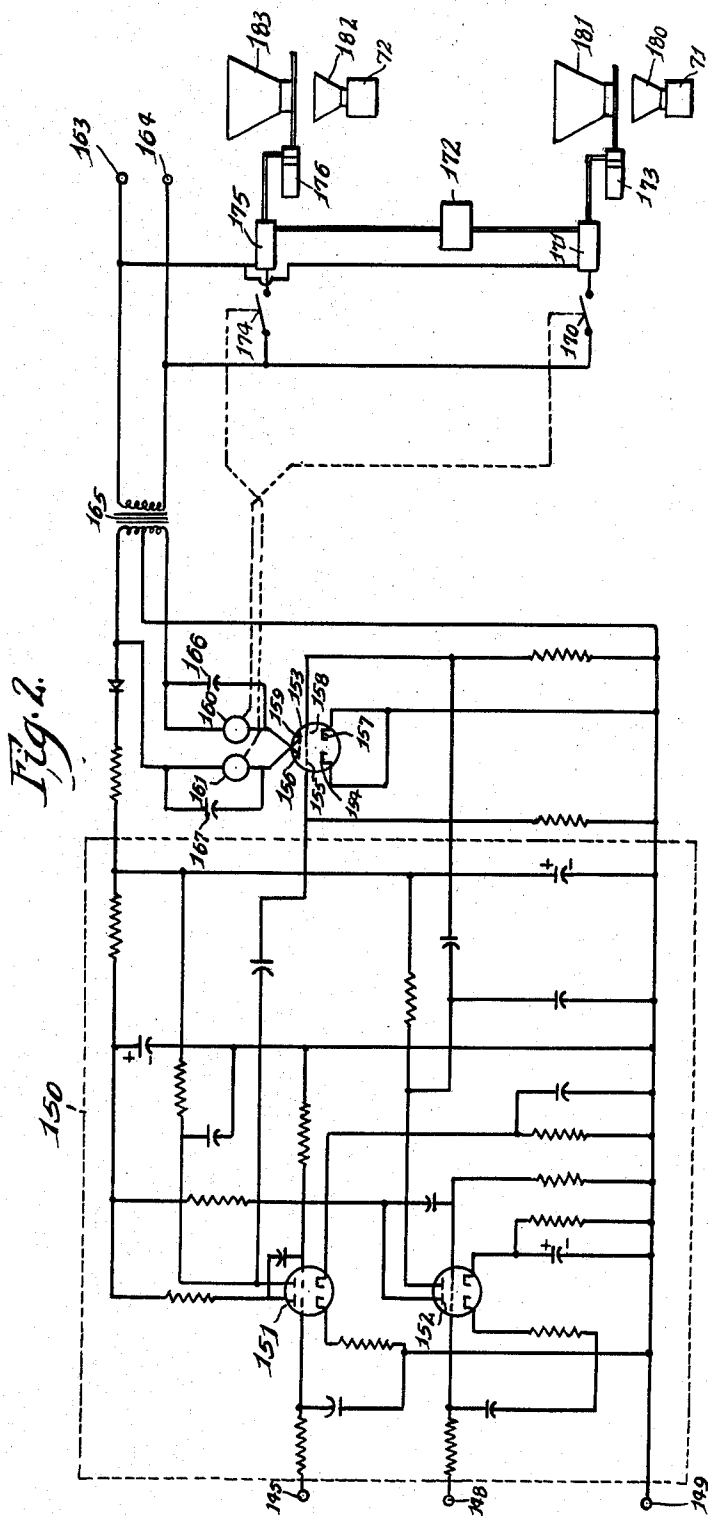
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4 Sheets-Sheet 2



Oct. 22, 1963

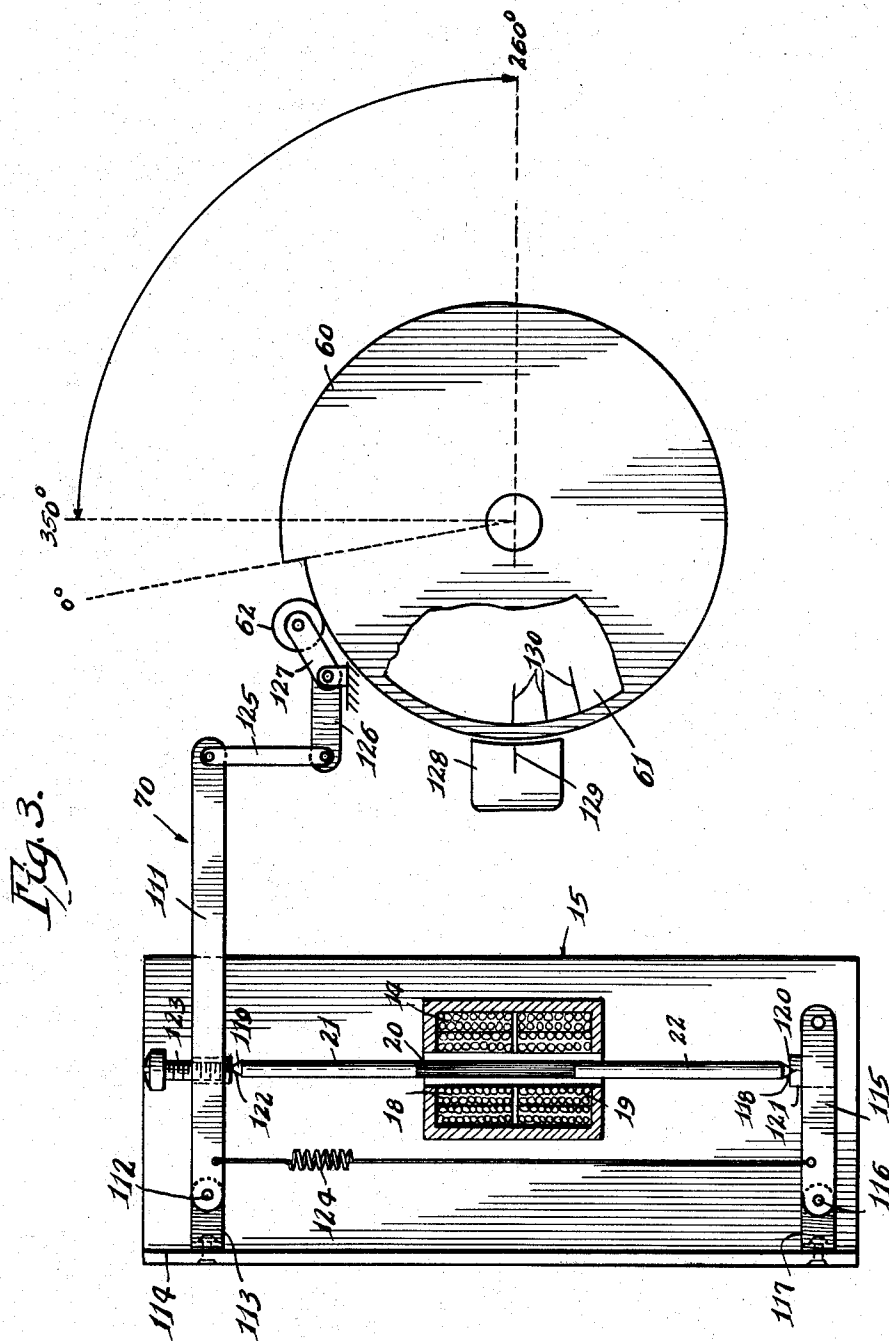
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Filed Aug. 31, 1961

4 Sheets-Sheet 3



Oct. 22, 1963

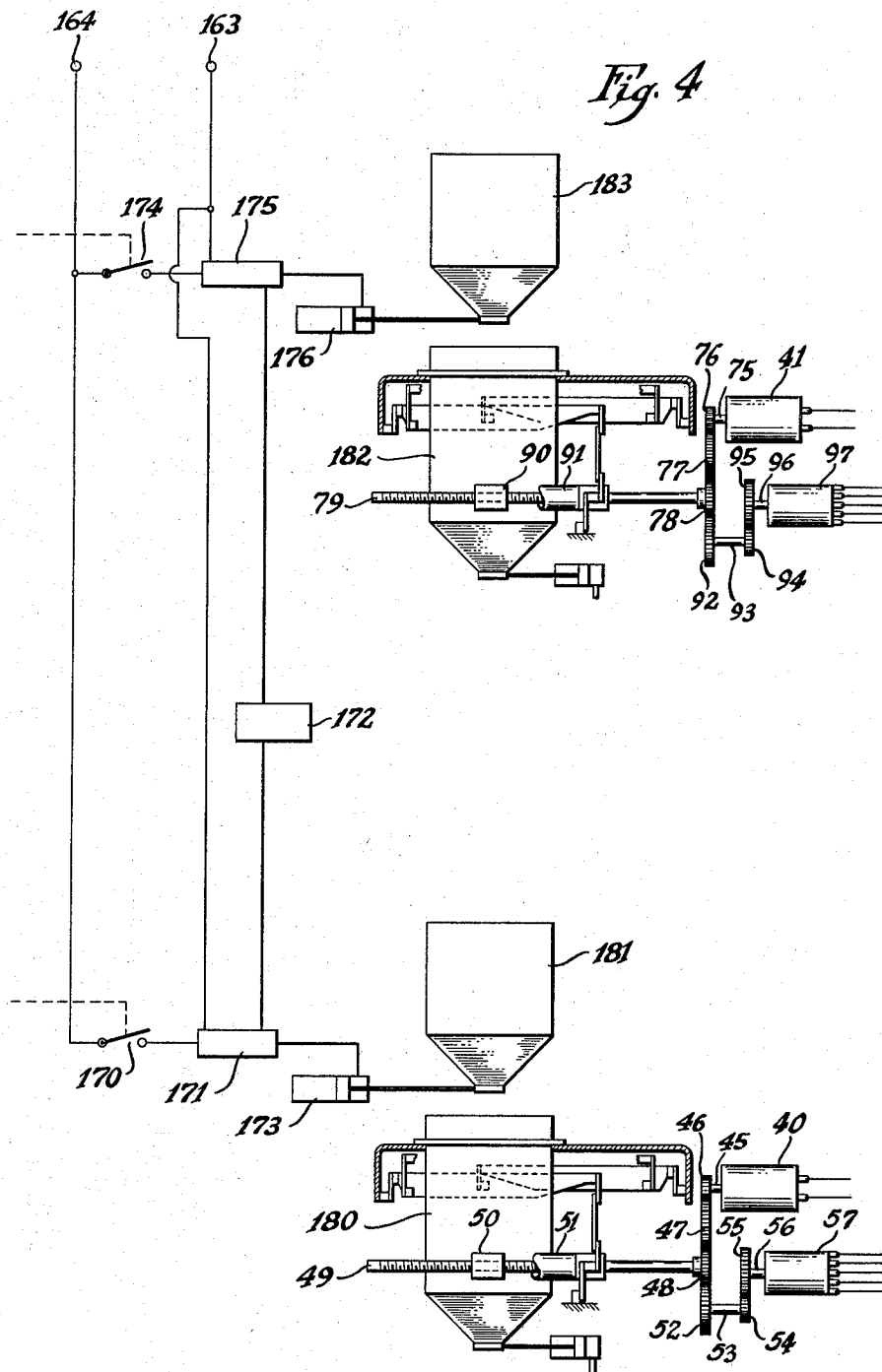
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ANTICIPATORY DEVICE FOR FILLING HOPPERS

Filed Aug. 31, 1961

4 Sheets-Sheet 4



1

3,107,820

ANTICIPATORY DEVICE FOR FILLING HOPPERS
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Filed Aug. 31, 1961, Ser. No. 135,269

16 Claims. (Cl. 222—53)

The present invention relates to an anticipatory device for sensing the rate at which a given operation is progressing in order to initiate a signal at a fixed time before the completion of that operation.

With the advent of automation in industry a need has arisen for devices which will initiate a second operation when only a fixed time remains before the completion of a first operation whose rate of progress may be varied. An example of such operation is found in a fluid or granular substance supply system wherein the substance must be supplied at a constant rate from a succession of two or more supply containers. Since a fixed time is required for each container to be filled and it is desirable to have a container filled no longer than absolutely necessary, it is desirable to begin filling a given container at a time interval which is equivalent to its filling time plus a reasonable safety interval. Since the discharge rate of each container may be varied, it is not practical to commence filling the next container in the succession when the amount of substance in the actively discharging container reaches a particular level or weight. Thus it is impractical to use a positive action device which is activated by a given level or weight of the remaining substance in an actively discharging container. The present invention will determine the rate at which the substance is being discharged from each sequential actively discharging container in order that the filling operation of the subsequent container will begin when there is a sufficient time remaining to completely fill that container.

Therefore it is an object of the present invention to provide a device which anticipates the completion of an operation of a variable duration by a fixed interval of time.

A further object of the present invention is to provide a device which anticipates the completion of a discharge of a substance from a container which has a variable discharge rate by a fixed interval of time.

An additional object of the present invention is to provide a new and improved device for anticipating the completion of an operation.

An additional object of the present invention is to provide a circuit utilizing a linear voltage differential transformer for determining the progression of a given operation.

Further objects and advantages will become apparent from the following detailed description taken in connection with the accompanying drawings, in which:

FIGURE 1 is a schematic diagram of a portion of an embodiment of the present invention;

FIGURE 2 is a schematic diagram of the remaining portion of the embodiment of the invention illustrated in FIGURE 1;

FIGURE 3 is an elevational view of a portion of the circuit illustrated in FIGURE 1 having a linear voltage differential transformer coil shown in section; and

FIGURE 4 is a partially schematic and partially diagrammatic illustration of a portion of an embodiment of the invention.

While this invention is susceptible of embodiments in many different forms, there is shown in the drawings and will be described in detail an embodiment of the present invention with the understanding that the present disclosure is to be considered as an exemplification of the

2

principles of the invention and is not intended to limit the invention to the embodiment illustrated. The scope of the invention will be pointed out in the appended claims.

In the embodiment of the present invention illustrated in FIGURES 1 through 4, the device which anticipates a given period of time before the completion of an operation by a system includes a control which may be varied to set the rate of progress of the drive system, a linear voltage differential transformer for sensing the actual progress of the system, a means for summing a signal from the control element and from the differential transformer to produce a resultant signal which is amplified and applied to the control element of an electronic valve and a relay controlled by the electronic valve to switch contacts when the resultant signal has a predetermined magnitude. The relay actuates the start of an operation of a fixed span of time that must be completed before the variable length operation of the drive system is completed. In the particular embodiment illustrated the drive system consists of a drive servo driving a scale poise which balances a substance container in a loss-of-weight type scale. The rotational motion of the screw driving the poise is geared to a synchro transmitter which is connected to a synchro receiver. A cam attached to the shaft of the synchro receiver is utilized to position a core of a differential transformer in order to provide a signal which is compared to a signal derived from a potentiometer which controls the rate of the servo drive motor. The resultant signal from summing these two signals is amplified and applied to the control grid of a vacuum tube which has a plate relay in its plate circuit. The plate relay controls the operation of an air valve which allows a substance to be discharged into the container of an inactive discharge container which is a part of another loss-of-weight type scale.

The circuit illustrated by FIGURES 1, 2 and 4 shows the utilization of two loss-of-weight type scales, each having its own drive system. Thus the problem solved by the present invention in the use of two scales is the filling of the container on the inactive scale in just sufficient time for it to commence discharging when the active discharging scale is fully discharged. The details of the structure of the loss-of-weight type scales are described in a co-pending application of Russell C. Turner and Raymond J. Walker, Serial No. 52,962, filed August 20, 1960. The present structure differs primarily in that a circuit, which triggers that commencement of the filling of an inactive scale container at a predetermined period before an actively discharging scale container completes its discharge, replaces the circuit which maintains the rate of discharge constant while the container is being refilled. Since multiple scales are being utilized in the present invention, it is only necessary to anticipate the length of time before the completion of a discharge from a given scale container for filling the subsequent container so that it will become loaded just prior to the completion of the discharge of the preceding scale. In the application, Serial No. 52,962, it was necessary to repeatedly refill the single scale container whenever it reached a sufficiently low weight of substance. The present embodiment of the invention illustrated in the figures includes the advantages over the scale circuit illustrated in the aforementioned application of being able to completely empty each scale container before reloading and of being able to automatically control the rate of discharge from each container which is automatically controlled at all times instead of being held constant for the period required for reloading.

The circuit illustrated by FIGURES 1, 2 and 4 will now be described in detail. An alternating current

3

source (not shown) is connected to a pair of terminals 10 and 11 which are connected by suitable lines across a primary coil 12 of a transformer 13, across a primary coil 14 of a linear voltage differential transformer 15 and across a primary coil 16 of a linear voltage differential transformer 17. The exact construction of the differential transformers 15 and 17 is more clearly illustrated in FIGURE 3 which includes a partial sectional enlarged view of the differential transformer 15. A pair of secondary coils 18 and 19, which are connected in an opposing relationship as illustrated by the circuit in FIGURE 1, are wound next to the primary coil 14. A core of ferromagnetic material 20 is supported by rods of non-magnetic material 21 and 22 by rigidly securing the rods 21 and 22 to the core 20. The position of the core 20 within the coils 14, 18 and 19 determines the relative amount of electrical energy being received by coils 18 and 19 from the coil 14. A similar core 23 and a similar pair of secondary coils 24 and 25 are included in the differential transformer 17. A phase shift means is composed of the transformer 13, a condenser 26 and a potentiometer 27 to first shift the phase of the signal received from the alternating current source 180° and to further shift the signal by 58° to compensate for the additional phase shift of 58° which occurs between the input and output of the differential transformers. The condenser 26 is connected in series with a resistor 28 and a potentiometer 30 across a portion of a secondary coil 31 of the transformer 13. The potentiometer 27 is connected to a junction point between the condenser 26 and the resistor 28 and to the secondary coil 31. The resistor 28 and the potentiometer 30 form a control element which is a control for poise rate servo amplifiers 32 and 33. A sliding contact 34 of the potentiometer 30 is connected to a switch 35 which alternatively selects the poise rate servo amplifier to be controlled at a given time. Thus, the setting of the sliding contact 34 in the potentiometer 30 is utilized to control the rate at which the servo drive motors will drive the poises. For this purpose, the amplifiers are connected to the servo drive motor 40 and a servo drive motor 41 respectively. When a switch arm 42 of the switch 35 is in the position to contact a terminal 43, the potentiometer 30, the poise servo amplifier 32 and the servo drive motor 40 are connected in series, and when the arm 42 is in the position to contact the terminal 44 the potentiometer 30, the poise servo amplifier 33 and drive motor 41 are connected in series.

The servo drive motor 40 has a drive shaft 45 with a gear 46 rigidly mounted thereon. An idler gear 47 meshes with the gear 46 and with a gear 48 which is rigidly mounted on a screw 49, to transmit rotary motion from the motor 40 to drive a scale poise 50 along the screw 49. The poise 50 and the screw 49 are mounted in a scale balance arm 51 which is pivoted to balance a substance container 180 (FIGS. 2 and 4) in the manner described in detail in the aforementioned patent application. A gear 52 mounted on a shaft 53 is driven by the gear 48 and transmits position information of the poise 50 through a gear 54, secured to the shaft 53, which meshes with a gear 55 mounted on a shaft 56 of a synchro transmitter 57. The synchro transmitter is electrically connected to a synchro receiver 58 which has a shaft 59 upon which a cam 60 and a dial 61 are rigidly mounted. A roller 62 rides on the cam 60 and is connected to the core 20 of the differential transformer 15 by a mechanical linkage, generally indicated at 70, which is utilized to position the core 20 in proportion to the rotary position of the cam 60.

The poise 50, the balance arm 51, the servo motor 40 and the synchro transmitter 57 are all contained within the general housing 71 (FIGS. 1 and 2) which contains a first loss-of-weight type scale mechanism.

The second drive system of which the servo motor 41 is the drive element contains a similar series of elements

4

consisting of a servo drive shaft 75, a gear 76 and an idler gear 77, a gear 78, a screw 79, a scale poise 90, a poise balance arm 91, a gear 92, a shaft 93, a gear 94, a gear 95, a shaft 96, a synchro transmitter 97 electrically connected to a synchro receiver 98, a receiver drive shaft 99, a cam 100 and a dial 101. A roller 102 is connected to the core 23 of the differential transformer 17 by a linkage generally indicated at 110, which is identical to the linkage 70.

The poise 90, the balance arm 91, the servo-motor 41 and the synchro transmitter 97 are all contained within the general housing 72 (FIGS. 1 and 2) which contains a second loss-of-weight type scale mechanism.

Referring to FIGURE 3, the mechanical linkage 70 consists of an arm 111 pivotally secured at 112 to a bracket 113 which is secured to a frame 114. Another arm 115 is pivotally secured at 116 to a bracket 117 which is rigidly secured to the frame 114. The rod structure composed of the core 20, the rods 21 and 22 is secured between the arms 111 and 115 by being pivotally secured at 118 and 119 by a cone-shaped depression 120 in a block 121 secured to the arm 115 and by a cone-shaped depression 122 in the end of a screw 123 which is threaded into the arm 111. A spring 124 connects the arms 111 and 115 to maintain the ends of the rods 21 and 22 in the cone-shaped depressions 120 and 122. The combination of the arms 111 and 115, the rod structure composed of the core 20 and rods 21 and 22 and the spring 124 forms a parallelogram which can be shifted as the arm 111 is rotated about the point 112. Thus, the core 20 can be inserted or retracted from the coils 14, 18 and 19 by rotating the arm 111. Arm 111 is connected to roller 62 through a link 125 and a pivoted rocker arm consisting of arms 126 and 127 rigidly fastened together. Link 125 is pivotally connected to arm 111 and arm 126. In order to maintain a proper amount of roller pressure on the cam 60, the linkage 70 is weight balanced. A stationary member 128 has an indicia 129 marked thereon to cooperate with a series of markings 130 on the dial 61, which indicates the percentage of a substance remaining in the container of the scale.

The resistors 28 and that portion of the potentiometer selected by the sliding contact 30 are connected across a pair of primary coils 138 and 139 of a transformer means 140. The transformer means 140 is actually a composite of two transformers wherein the primary coils 138 and 139 are connected in parallel with each other and the secondary coils 141 and 142 are essentially independent of each other. One end of the secondary coil 141 is connected to a sliding contact 143 on a potentiometer 144 which is connected across the secondary coils 18 and 19 of the differential transformer 15, and the other end of the coil is connected to a terminal 145. In a similar manner, one end of the coil 142 is connected to a sliding contact 146 of the potentiometer 147 which is connected across the secondary coils 24 and 25 of the differential transformer 17, and the other end of the coil is connected to a terminal 148. Thus the alternating current signal from the alternating source received across the terminals 10 and 11 is supplied to the two differential transformers 15 and 17 and to the transformer 13. The signal from the differential transformers 15 and 17 are individually summed with the signal from the transformer 13 and the following phase shift network of condenser 26 and potentiometer 27 in the transformer means 140 to produce a pair of resultant signals which appear between the terminal 145 and a common ground terminal 149 and the terminal 148 and the ground terminal 149 respectively.

Referring now to FIGS. 2 and 4, a two stage, two channel electronic amplifier generally indicated within the dashed lines 150 has the input to one channel connected to the terminal 145 and the input to the other channel connected to the terminal 148. A common ground of the amplifier is connected to the terminal 149. Each channel of the amplifier 150 contains a dual triode construc-

tion in a single evacuated envelope as indicated at 151 and 152. Each dual triode is utilized in a conventional manner as will be noted by those skilled in the art to provide a two-stage amplifier whose output is connected to a dual triode tube 153 in a single evacuated envelope. One triode of the dual triode tube 153 consists of a cathode 154, a control element or grid 155, and an output element, which is a conventional anode 156. The other triode consists of a cathode 157, a control element or grid 158 and an output element or anode 159. The control element 155 is connected to the output of the tube 151 and the control element 158 is connected to the output of the tube 152. A pair of relays 160 and 161 have relay coils connected to the anodes 156 and 159 respectively. An anode power circuit includes the coils of the relays 160 and 161 and is connected across the terminals 163 and 164 through the transformer 165. A second alternating current source (not shown) is connected to the terminals 163 and 164 to supply an alternating current across the triodes controlling the relays. A condenser 166 is connected in parallel with the relay 160 and a condenser 167 is connected in parallel with the relay 161. The relay 160 is mechanically connected to an electrical switch 170, which it closes upon being energized, to supply an electrical current to an air valve 171 from the terminals 163 and 164. The air valve in turn controls a flow of air from a compressor 172 to an air piston 173 which opens a valve to allow a supply of a desired substance to flow into a first substance container 180 of a first loss-of-weight type scale from a supply hopper 181. Similarly, the relay 161 is mechanically connected to a switch 174 which closes the switch which connects the air valve 175 to the terminals 163 and 164 to operate the valve and to thereby utilize the air piston 176 to allow a substance to flow into a second substance container 182 of a second loss-of-weight type scale from a supply hopper 183.

Referring again to all the FIGURES 1 through 4 the operation of the embodiment of the invention illustrated in these figures will now be described in greater detail. The first alternating source connected to the terminals 10 and 11 supplies an alternating signal to both differential transformers 15 and 17 and to the transformer 13. Unlike the 180° phase shift found in most transformers, the differential transformers have a phase shift of 58°. The signal extracted from the differential transformers has this 58° phase lag and its magnitude is dependent upon the position of the core relative to the coils. When the core 20 or 23 is symmetrically positioned in respect to the coils 18 and 19, the amplitude of the alternating current signal is zero. As the core is displaced from a symmetrical position the amplitude of the differential transformer output signal increases, the phase depending on the direction of displacement of the core. The cores are not removed far enough that the amplitude of the output will again drop. The output of transformer 13 will be in phase with the signal across the primary coil. The potentiometer 27 may be adjusted to compensate for the additional 58° lag in the differential transformers so that the reference signals arriving at the secondary coils of the transformer means 140 are exactly 180° out of phase with the signal arriving from the differential transformers. The transformer means 140 causes the usual 180° phase shift in the signal applied to its primary coils 138 and 139. The signal arriving at the primary coils of the transformer means 140 is controlled in amplitude by the setting of the sliding contact 34 of the potentiometer 30, which also controls the discharge rate of the scale to which the switch 35 connects the potentiometer 30. Let it thus be assumed then that the switch 35 is in the position shown in FIGURE 1 where it is controlling the servo amplifier 32 and thereby controlling the discharge rate of the first container 180 by controlling the rate at which the poise 50 is moved along the beam 51. The higher rate that is dictated by the setting of the potentiometer 30, the earlier

in the discharge process of scale 1 the filling of scale 2 must begin. When the potentiometer 30 is set for a higher rate of the drive motor, it will produce a higher voltage across the primary coils of the transformer means 140. The transformer means 140 reduces the maximum voltage that can be obtained from transformer 13 to 0.49 volt for a maximum setting on the potentiometer 30. The range of the voltage received at the secondary of the transformer means 140 from the differential transformers is from 0 to 0.5 volt. Let it be assumed that the potentiometer is set for a maximum rate which places 0.49 volt on the secondary of transformer means 140 and that the differential transformer voltage at the secondary of the transformer 140 is initially 0.5 volt. This maximum value of 0.5 volt is established by the setting of the sliding contact 143 for the differential transformer 15 and by the setting of the sliding contact 146 for the differential transformer 17.

Referring for the moment to FIGURE 3, it will be noted that there is no rise in the cam for the first 260° of rotation. From 260° of rotation to 350° of rotation the core will be inserted into the differential transformer so that the reference voltage is reduced from the time the cam has reached 260° of its revolution. The reference signal from the differential transformer has initially exceeded the signal from the rate potentiometer 30 by a minimum of 0.01 volt if the potentiometer is set for its maximum rate and by a larger amount when it is set for a lower rate.

There will be a flow of electrons through the triodes having their control elements 155 and 158 connected to the transformer means 140 when the voltage on the anodes 156 and 159 is positive and the voltage from the transformer 140 is also positive and in phase with the anode voltage. On the negative half cycle of the voltages applied to the anodes 156 and 159 no current will flow through the anodes. Thus to have a current flow in a triode and thereby have a current flow through the relay coil of relay 160 or 161, the resultant signal from the transformer 140 must be in phase with the anode voltage when the anode voltage is on its positive half cycle. In fact, it requires an in phase 0.01 volt resultant signal to obtain a sufficient current to actuate the relay 160 or 161 in the embodiment being illustrated. Thus, the voltage from the linear transformer must drop to .48 volt before a relay is actuated.

As the setting of the potentiometer 30 is reduced, the voltage from the differential transformer must drop even lower before an in phase resultant signal of 0.01 volt amplitude is transmitted to the triode which has an anode connected to the relay 160 before it will allow a sufficient voltage to actuate the relay 160. When the relay 160 does operate, it closes the switch 170 actuating the air valve 171 to operate the air piston 173 and commence the flow of a substance into the container of the first scale. Thus it may be seen that as the rate potentiometer decreases the rate of the variable event, it takes longer to reach the time at which an in phase 0.01 volt is realized at the output of the transformer means 140 and thus this time is deferred closer to the end of the variable discharge. The time interval between the realization of an in phase 0.01 volt resultant signal and the end of the variable discharge regardless of the rate of the variable discharge is a fixed period of 2.5 minutes. This fixed period of time is required to fill the inactive scale. The differential transformer 17, relay 161, switch 174, air valve 175 and air piston 176 operate in the same manner as the respective elements just described.

When the container of the actively discharging scale has completely discharged itself, any appropriate mechanism may be utilized to commence the discharge of the previously inactive scale while the previously active scale awaits a resultant signal through the other channel of the amplifier to trigger its relay when there is just two

and one-half minutes remaining before it must become active again. Thus it may be seen that the material remains in each container for a minimum of time before starting its discharge while the rate of discharge may be controlled throughout the discharge of each container as described in the aforementioned application Serial No. 52,962.

It will be apparent to those skilled in the art that although vacuum tubes are utilized in the embodiment of the invention present here, other electronic valves such as transistors or magnetic amplifiers could be utilized either in the amplifier or for the triodes which control the relays. Thus the scope of the present invention is intended to cover the utilization of all electronic valves for such a function. It will be recognized by those skilled in the art that the summing transformer means may take many different forms within the scope of the present art and the claims of the present invention are intended to include all such alternate forms for summing to alternating current signals. In addition, the control systems may be utilized for governing many other types of operations which have a variable time of completion. While a dual scale apparatus has been illustrated, the circuit illustrated can be easily modified to control any number of apparatus in a sequential manner by adding a sufficient number of additional channels.

I claim:

1. An anticipatory device comprising a linear voltage differential transformer having a core, a primary coil and secondary coils, a control means, a drive system for performing an operation having a termination point wherein the velocity of said drive system is controlled by said control means, a cam actuated in proportion to the progress of said drive system, linkage means between said cam and said core for moving said core in relative relationship to said coils, an alternating current source connected across said control means and said primary coil of said differential transformer, and a means for summing a signal from said control means and a signal from said secondary coils to produce a resultant signal, whereby said resultant signal indicates the interval of time remaining before said termination point.

2. An anticipatory device as specified in claim 1, wherein said means for summing said signals is a transformer.

3. An anticipatory device as specified in claim 1, wherein said means for summing said signals is a transformer having a primary coil connected to the control means and a secondary coil connected to said secondary coils of said differential transformer.

4. An anticipatory device comprising a linear voltage differential transformer having a core, a primary coil and secondary coils, a control means, a drive system for performing an operation having a termination point wherein the velocity of said drive system is controlled by said control means, a cam actuated in proportion to the progress of said drive system, linkage means between said cam and said core for moving said core in relative relationship to said coils, an alternating current source connected across said control means and said primary coil of said differential transformer, means for summing a signal from said control means and a signal from said secondary coils to produce a resultant signal signal connected to said control means and said secondary coils and a phase shift means interconnected between any of the elements of said device to cause the signal from the control means to be 180° out of phase with the signal from the secondary coils, whereby said resultant signal indicates the interval of time remaining before said termination point.

5. An anticipatory device comprising a linear voltage differential transformer having a core, a primary coil and secondary coils, a variable potentiometer, an electrical servo system for performing an operation having a termi-

nation point having a servo drive motor, a synchro transmitter and a synchro receiver wherein the rotational velocity of said motor is controlled by said potentiometer, a cam driven by said synchro receiver, linkage means between said cam and said core for moving said core in relative relationship to said coils, means for shifting the phase of a signal connected across said potentiometer, an alternating current source connected across said phase shift means and said primary coil of said differential transformer, and means for summing said signal from said potentiometer and said secondary coils to produce a resultant signal, whereby said resultant signal indicates the interval of time remaining before said termination point.

6. An anticipatory device comprising a linear voltage differential transformer having a core, a primary coil and secondary coils; a variable potentiometer; an electrical servo system for performing an operation having a termination point having a servo drive motor, a synchro transmitter and a synchro receiver wherein the rotational velocity of said motor is controlled by said potentiometer; a cam driven by said synchro receiver; linkage means between said cam and said core for moving said core in relative relationship to said coils; means for shifting the phase of a signal consisting of a transformer having a primary coil and a secondary coil connected across said potentiometer; a condenser connected in series with said secondary coil and said potentiometer and a resistor connected in parallel with said potentiometer; an alternating current source connected across said phase shift means and said primary coil of said differential transformer; and means for summing said signal from said potentiometer and said secondary coils to produce a resultant signal, whereby said resultant signal indicates the interval of time remaining before said termination point.

7. An anticipatory device comprising a drive system for performing an operation having a termination point, a control means controlling the velocity of said drive system by producing a control signal, means for producing a first alternating current signal whose amplitude is proportional to said control signal, means for producing a second alternating current signal whose amplitude is proportional to the progress of said drive system and is 180° out of phase from said first signal, a transformer means for summing said signals to produce a resultant signal, an electronic valve having an output element and a control element, said control element being connected to said transformer means, and a switching device connected to said output element, whereby said switching device is energized at a desired interval of time before said termination point.

8. An anticipatory device comprising a linear voltage differential transformer having a core, a primary coil and secondary coils; means for varying the amplitude of an alternating current; a drive system for performing an operation having a termination point controlled by said means; a means connected to said drive system for positioning said core in said transformer; a first alternating current source connected to said means for varying the amplitude of an alternating current and to said primary coil; means for placing a signal from said amplitude varying means 180° out of phase with a signal from said secondary coils; a transformer connected to said secondary coils of said differential transformer and to said means for varying the amplitude of an alternating current; an electronic valve having an output element and a control element, said control element being connected to said transformer, said output element being connected to a second alternating current source which is in phase with the signal from said secondary coils of said differential transformer; and a relay having a relay coil connected in series between said output element and said second alternating current source, whereby said relay is energized at a desired interval before said termination point.

9. An anticipatory device comprising a linear voltage differential transformer having a core, a primary coil and secondary coils; means for varying the amplitude of an alternating current; a drive system for performing an operation having a termination point controlled by said means, a means connected to said drive system for positioning said core in said transformer; a first alternating current source connected to said means for varying the amplitude of an alternating current and to said primary coil; means for placing a signal from said amplitude varying means 180° out of phase with a signal from said secondary coils; a transformer connected to said secondary coils of said differential transformer and to said means for varying the amplitude of an alternating current; a vacuum tube having an anode, a cathode, and a control element, said control element and said cathode being connected to said transformer, said anode and said cathode being connected in series across a second alternating current source which is in phase with the signal from said secondary coils of said differential transformer; and a relay having a relay coil connected in series between said anode and said second alternating current source, whereby said relay is energized a desired interval before said termination point.

10. An anticipatory device comprising a linear voltage differential transformer having a core, a primary coil and secondary coils; means for varying the amplitude of an alternating current; a drive system for a scale poise of a feed system having a container balanced by the poise controlled by said means to drive said poise at a steady rate for a given distance; a means connected to said drive system for positioning said core in said transformer; a first alternating current source connected to said means for varying the amplitude of an alternating current and to said primary coil; means for placing a signal from said amplitude varying means 180° out of phase with a signal from said secondary coils; a transformer connected to said secondary coils of said differential transformer and to said means for varying the amplitude of an alternating current; at least one vacuum tube connected in series with said transformer; an additional vacuum tube having an anode, a cathode, and a control element, said control element and said cathode being connected to the last vacuum tube in the series of said at least one vacuum tube; said anode and said cathode being connected in series across a second alternating current source which is in phase with the signal from said secondary coils of said differential transformer; a relay having a relay coil connected in series between said anode and said second alternating current source; and a control for releasing a flow of material in said container connected to said relay, whereby said flow of material is released at desired interval of time before termination of the driving of said poise.

11. An electrical control device comprising a multiplicity of linear voltage differential transformers having a core, a primary coil and secondary coils; means for varying the amplitude of an alternating current; an equal multiplicity of drive systems alternatively controlled by said means; a means for positioning each said core in each said transformer connected to each one of said drive systems; a first alternating current source connected to said means for varying the amplitude of an alternating current and to said primary coils; means for shifting a signal from said amplitude varying means 180° out of phase with a signal from said secondary coils; a transformer means connected to said secondary coils of said differential transformers and to said means for varying the amplitude of an alternating current; a multiplicity of vacuum tubes having an anode, a cathode, and a control element, each said control element and said cathode being connected to a portion of said transformer means, each said anode and said cathode being connected in series across a second alternating current source which is in phase with the signal from said secondary coils of said differential transformers; and a multiplicity of separate

relays, each having a relay coil connected in series between one said anode and said second alternating current source.

12. An electrical control device comprising a linear voltage differential transformer having a core, a primary coil and secondary coils; a variable potentiometer; an electrical servo system having a servo drive motor, a synchro transmitter and a synchro receiver wherein the rotational velocity of said motor is controlled by said potentiometer; a cam driven by said synchro receiver; linkage means between said cam and said core for moving said core in relative relationship to said coil; an alternating current source connected across said potentiometer and said primary coil of said differential transformer; means for placing a signal from said potentiometer 180° out of phase with a signal from said secondary coils; a transformer connected to said secondary coils of said differential transformer and to said means for varying the amplitude of an alternating current; a vacuum tube having an anode, a cathode, and a control element, said control element and said cathode being connected to said transformer, said anode and said cathode being connected in series across a second alternating current source which is in phase with the signal from said secondary coils of said differential transformer; and a relay having a relay coil connected in series between said anode and said second alternating current source.

13. An electrical control device comprising a multiplicity of linear voltage differential transformers having a core, a primary coil and secondary coils; a variable potentiometer, an equal multiplicity of electrical servo systems, each said system having a servo drive motor, a synchro transmitter and a synchro receiver wherein the rotational velocity of said motor is alternatively controlled by said potentiometer; a cam driven by each synchro receiver; linkage means between each cam and core for moving said core in relative relationship to said coil; an alternating current source connected across said potentiometer and said primary coils of said differential transformers; means for placing a signal from said potentiometer 100° out of phase with signals from said secondary coils; a transformer means connected to said secondary coils of said differential transformers and to said means for varying the amplitude of an alternating current, a multiplicity of vacuum tubes, each said tube having an anode, a cathode, and a control element, each said control element and said cathode being connected to a portion of said transformer means, each said anode and said cathode being connected in series across a second alternating current source which is in phase with the signal from said secondary coils of said differential transformers; and a separate relay coil connected in series between each said anode and said second alternating current source.

14. An electrical control device comprising a multiplicity of linear voltage differential transformers having a core, a primary coil and secondary coils; a variable potentiometer; an equal multiplicity of electrical servo systems, each said system having a servo drive motor, a synchro transmitter and a synchro receiver wherein the rotational velocity of said motor is alternatively controlled by said potentiometer; a cam driven by each synchro receiver; linkage means between each cam and core for moving said core in relative relationship to said coil; an alternating current source connected across said potentiometer and said primary coil of said differential transformers; means for placing a signal from said potentiometer 180° out of phase with signals from said secondary coils; a transformer means connected to said secondary coils of said differential transformer and to said means for varying the amplitude of an alternating current; a multiplicity of amplifiers, each connected to a portion of said transformer means, a multiplicity of electronic valves each having an output element and a control element, each said control element being con-

11

connected to one of said amplifiers, said output element being connected to a second alternating current source which is in phase with the signal from said secondary coils of said differential transformers; and a separate relay having a relay coil connected in series between each said anode and said second alternating current source.

15. A control system comprising a plurality of controlled rate discharge devices, each of said devices having a filling operation requiring a fixed period of time and a discharge operation requiring a variable but greater period of time, means for sequentially discharging said devices, means for sequentially initiating the commencement of the filling operation of a discharge device when an interval of time equivalent to the filling operation of said discharge device remains before the discharge period of another of said devices is concluded.

16. A control system comprising a pair of controlled

12

rate discharge devices, each device having a filling operation requiring a fixed period of time and a discharge operation requiring a variable but greater period of time, means for sequentially discharging said devices, means for sequentially initiating the commencement of the filling operation of a discharged device when an interval of time equivalent to the filling operation of said discharged device remains before the discharge period of the other of said devices is concluded.

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