June 3, 1947. J. E. COLLINS 2,421,481

SEQUENCE CONTROLLER

Filed Sept. 7, 1944 4 Sheets-Sheet 1

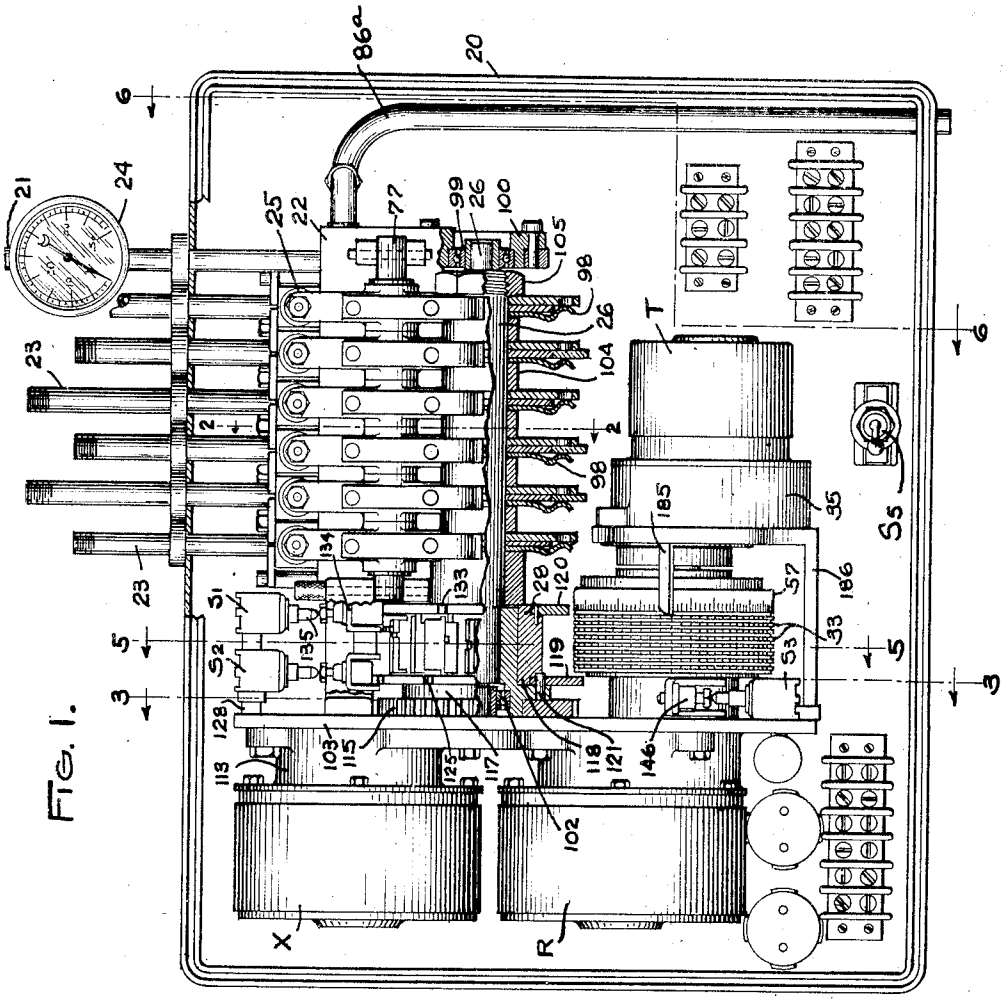


FIG. 1.

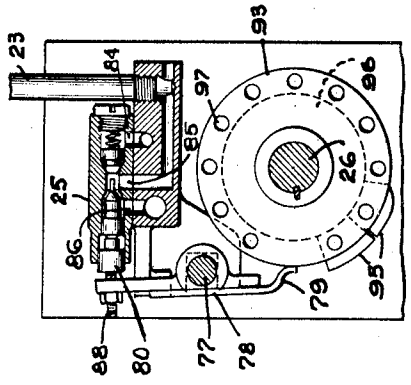


FIG. 2.

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FIG. 4.

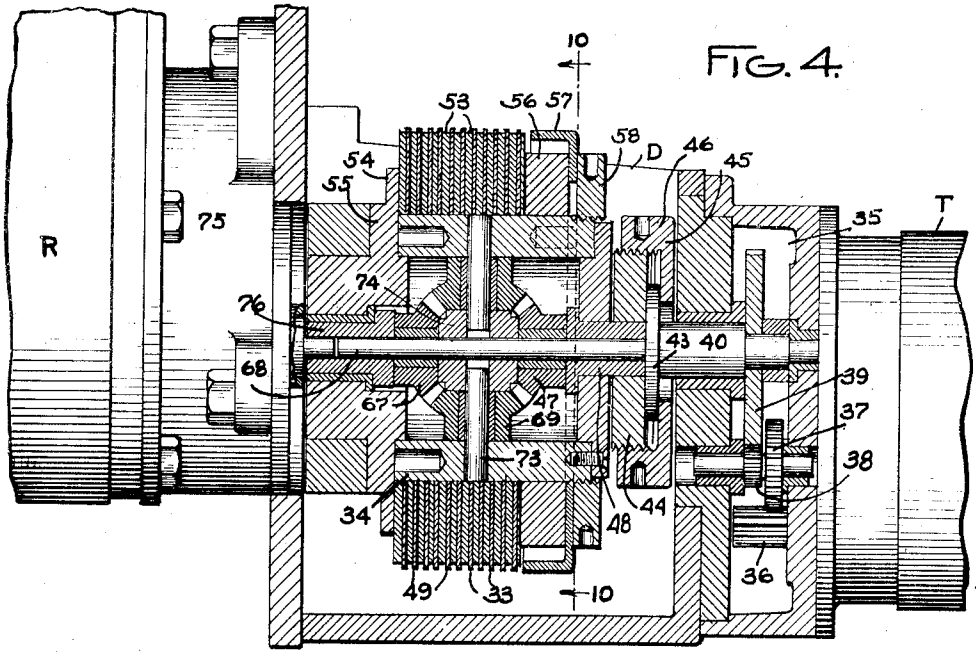
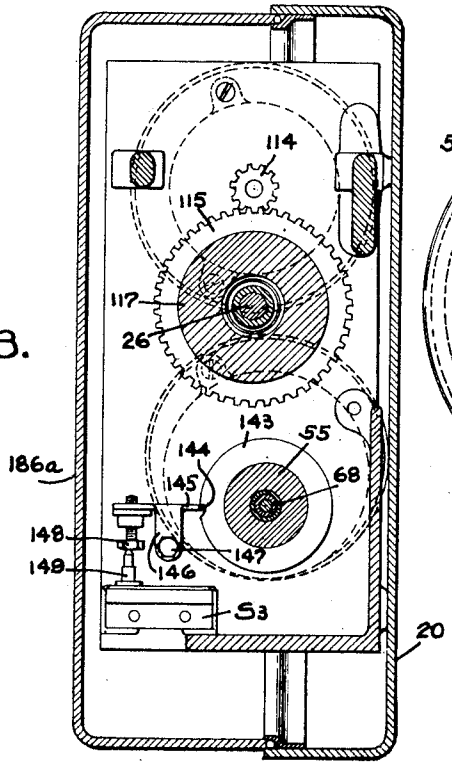


FIG. 3.



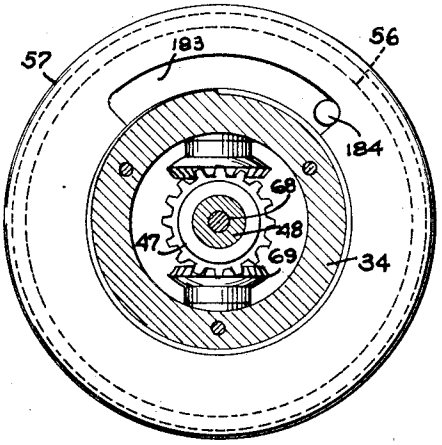


FIG. 10.

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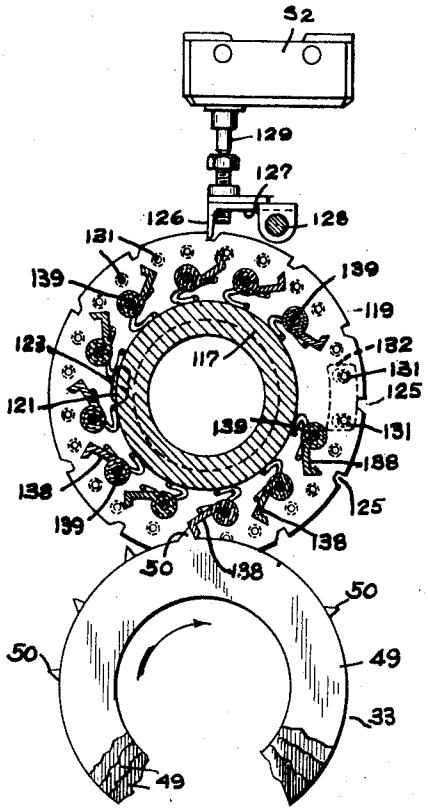


FIG. 5.

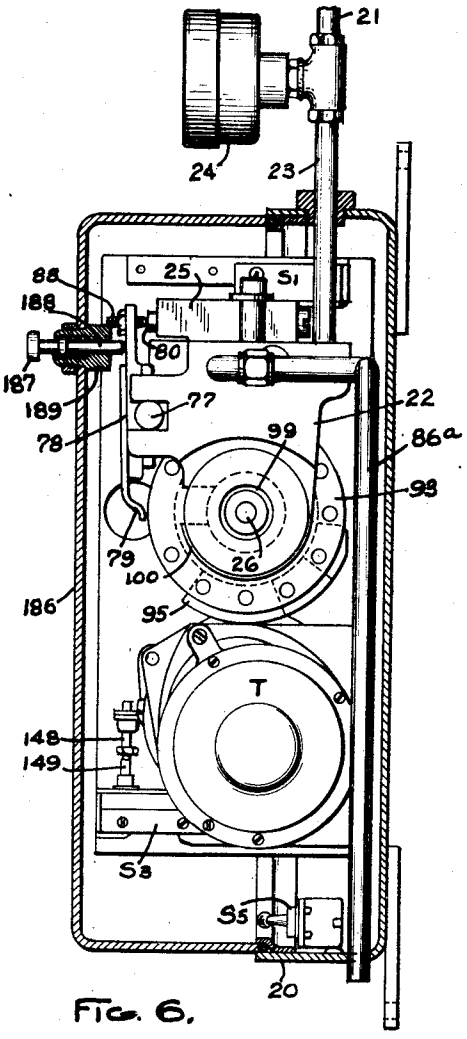


FIG. 6.

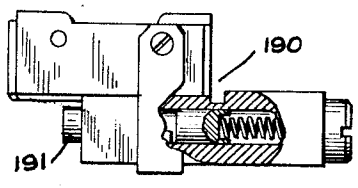


FIG. 8.

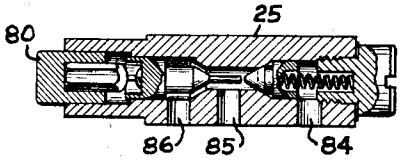


FIG. 7.

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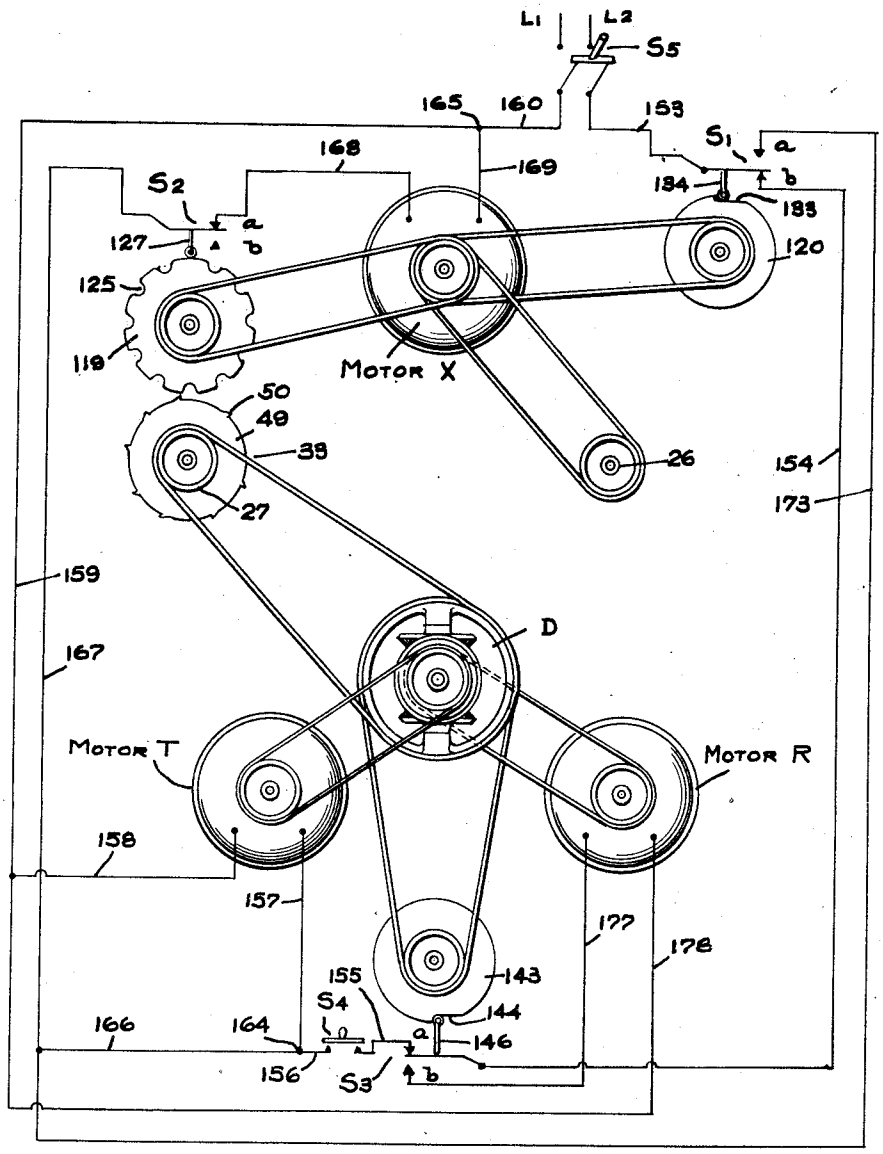


FIG. 9.

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Patented June 3, 1947

2,421,481

UNITED STATES PATENT OFFICE

2,421,481

SEQUENCE CONTROLLER

John E. Collins, Akron, Ohio, assignor to The Sinclair-Collins Valve Company, Akron, Ohio, a corporation of Ohio

Application September 7, 1944, Serial No. 552,975

6 Claims. (Cl. 161—7)

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The invention relates to improvements in time-cycle controllers of the type used to control regular sequences of operations, or similar repetitive processes.

An object of the invention is to provide novel and improved mechanism for operating a plurality of pilot valves, pilot switches, or devices of this nature in a repetitive sequence of operations such as indicated above.

Another object of the invention is to provide novel means, responsive to movement of a plurality of timing trips, and sensitive to relatively gentle impulses, for transferring the initiating effect of said timing trips to a further series of independently driven operating cams which operate the aforesaid pilot elements such as switches, valves or the like.

Another object of the invention is to provide novel means of the nature described, and wherein the aforesaid timing trips advance continuously to respective operating positions at relatively low speed, but wherein the aforesaid operating cams advance only intermittently, by successive increments, at relatively high speed.

Another object of the invention is to provide means whereby the relatively heavy load imposed upon the operating shaft is assumed by an independently driven power source, said power source being energized as aforesaid ultimately from timing trips, the operation of said timing trips imposing only a relatively light load upon their own power source, there being an initiating agent disposed in operational sequence between said timing trips and said operating shaft and capable of instituting energization of said operating shaft responsive to movement of said timing trips.

Another object is to provide improved control means for the regulation of a repetitive cycle, said control means being simple, reliable, and sturdy, and easily operated, requiring little or no addition of accessories or substitution thereof, and no trained operators to make set-ups or alterations.

Other objects and advantages of the present invention, and suitable structures embodying the same, are disclosed in the present specification and accompanying drawings, and the essential features thereof are set forth in the claims.

In the drawings,

Fig. 1 is a front elevational view of a time-cycle controller assembly embodying the present invention, the controller being shown in a housing, but with the front cover removed;

Fig. 2 is a vertical sectional view taken on the line 2—2 of Fig. 1;

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Fig. 3 is a vertical sectional view taken on the line 3—3 of Fig. 1,

Fig. 4 is a fragmentary view, partly in vertical section, partly in front elevation, and somewhat enlarged, showing details of the timing cam assembly and driving mechanism;

Fig. 5 is a fragmentary sectional view, somewhat enlarged and with parts broken away, taken on the line 5—5 of Fig. 1.

Fig. 6 is a vertical sectional view taken on the line 6—6 of Fig. 1.

Fig. 7 is a longitudinal sectional view of a three-way pilot valve such as may be controllable by one of the operating cams shown in Figs. 1 or 3.

Fig. 8 is a side elevation, partly in section, showing a suitable switch arrangement for use instead of the pilot valve of Fig. 7.

Fig. 9 is a schematic showing of the operating elements of my cycle controller, in conjunction with a simplified wiring diagram.

Fig. 10 is a vertical sectional view taken on the line 10—10 of Fig. 4.

The improved cycle controller which embodies the present invention is suitable for use in many industrial applications, but for convenience, and in no sense of limitation, I have illustrated but one embodiment thereof as used for example in the rubber molding or plastic casting industries. Such industries utilize large presses, operated frequently by hydraulic controls and embodying a plurality of rams, platens, or dies actuated by pistons reciprocable in power cylinders. Many presses of this type are accordingly equipped with a plurality of fluid power conduits in communication with the power cylinders, the transmission of the fluid power from the power source to such conduits being controlled by pilot devices such as valves, switches, or the like. The present invention is directed to novel mechanism for the operation of such pilot devices by controlling the successive times of initiation of operation of each such pilot device, and also the length of the period during which each such pilot device transmits or interrupts the flow of power. While the particular embodiment here illustrated is electromechanical in nature, and controls the flow of fluid power through a plurality of conduits by controlling the chronological sequence of operations of a respective plurality of valves, it is obvious that any one skilled in the art, on a study of the following specification and accompanying drawings, could readily vary the device in detail by substituting switches for valves, or otherwise effecting non-essential changes with-

out departing from the spirit and scope of the invention.

General description of the controller

The mechanism illutrated is designed to cause the operation of a plurality of control devices in any desired sequence or order during one complete cycle of operations. It includes a rotatable member having actuators, one or more for each control device, and provided with motor operated indexing means energized at intervals to turn said member one step—a fraction of a complete turn. Indexing movement is at relatively high speed in order to secure quick operation of each control device when actuated.

Intermittent energization of the indexing motor is effected by a control wheel driven by its own continuously operating timing motor and making one revolution per cycle. Said control wheel rotates slowly, and carries trips distributed around its axis and adapted in turn, at one point in their path of travel, to initiate operation of the indexing motor, which thereupon maintains its own circuit closed and later opens it to terminate the indexing operation.

A third reset motor is utilized to quickly restore all parts to initial position and do away with unnecessary delay under certain conditions.

The specific embodiment shown comprises a work-performing rotatable shaft, disposed to be intermittently advanced through increments of rotation in a cyclic process, an indexing motor which, when intermittently energized, produces said increments of rotation of said shaft, a continuously operating timing trip assembly driven by a timing motor, a control wheel carried by, and normally rotatable with said shaft, but capable of a limited amount of play or free movement on said shaft, said control wheel being susceptible to initiation of free movement by any one of the timing trips coming in contact therewith, a switch in the circuit to said indexing motor, and disposed to be actuated by each said initiation of free movement of said control wheel to close said circuit to said indexing motor whereby said shaft completes an increment of rotation causing said wheel to rotate therewith, and means carried by said wheel for actuating said switch to break the circuit to said indexing motor at the end of said increment of shaft rotation.

The embodiment shown further comprises a second switch means actuated by said control wheel towards the end of a complete rotation thereof, and disposed, when so actuated, to close a circuit to a third or reset motor, whereby the trip assembly is restored to starting position.

In said specific embodiment now to be described, the invention is adapted to automatically control the intermittent transmission of fluid pressure through a plurality of conduits from a fluid pressure source, the said conduits conveying the fluid pressure to perform various operations such as to advance a ram, or change its speed of movement or vary the pressure secured thereby, or apply heating steam or cooling water, or otherwise control a plurality of operations of a machine.

It will be obvious as the description proceeds that each individual conduit intermittently transmits fluid pressure responsive to the control of its own valve, and that in each complete cycle the said valve may be opened and closed once, twice, or any desired plurality of times, in any desired chronological sequence, responsive to the number and arrangements of valve-controlling elements operated by the controller during the cycle.

Speaking first generally, and with occasional reference to Fig. 1, the apparatus here shown comprises a combination of operating elements housed in a casing **20**, the front cover of which has been omitted from the drawings. Fluid power is supplied through an inlet conduit **21** to a manifold **22**. The manifold is provided with a plurality of outlet conduits **23**, **23** and with a conventional pressure gage **24**. Each conduit **23** transmits fluid pressure in response to opening of its respective valve **25**, which in turn is operated by one of a series of operating cams carried on an operating cam shaft **26**. Cam shaft **26** is driven by an indexing motor X which is intermittently energized by timing means later to be more fully described.

The principal operating elements of said timing means may here be generally described. They include a timing motor T which drives a timing drum **34**. Said drum **34** carries, on its outer periphery, a plurality of cam disks having timing trips or fingers whose operation and interrelation will later be described, but it may be here mentioned that the purpose of the said trips is to intermittently initiate operation of the indexing motor X heretofore mentioned, and thereby periodically bring the operating cams on shaft **26** to their operating positions so as to actuate the proper fluid valves.

Intermittent energization of the indexing motor X is effected through suitable electric circuits and switches therefor, to be later described in detail, several of said switches being operated by a rotatable element **28**, hereinafter termed a control wheel, which is moved periodically through fractional increments of rotation by the arrival of successive timing trips at operating position, as will appear.

At the close of each cycle the timing cam assembly on timing drum **34** is rapidly moved to zero position or starting position by a reset motor R which is energized only for this particular task and which is geared to perform its function without loss of time. As is now apparent, motion of the timing drum may be produced either by timing motor T or reset motor R, coupling between both motors and the drum being achieved through a differential gearing D within the drum.

Previously known cycle controllers of the general purpose herein described have used a continuously rotating, operating cam shaft to actuate the pilot valves. Since the cycle of operations was controlled by a single rotation of such shaft, and since a cycle might be as long as 60 minutes or more, the operating shaft necessarily rotated at very low speed. The operating cams consequently engaged their respective pilot valves or switches very gradually, making it almost impossible to secure rapid valve operation, or accuracy of timing, without the interposition of some sort of snap-over device or other mechanical expedient to insure rapid operation. It is apparent, however, that such expedients do not insure accuracy in timing.

In the controller herein disclosed, the timing cam trips rotate slowly, but during such rotation, at appropriate times, they cause actuation of a switch which is operated by only a slight increment of motion. The circuit to motor X is thereby energized, and the operating cam shaft is rotated at relatively high speed. Pilot valves may accordingly be rapidly opened to intake or

exhaust at exact times. By this means it is possible to use an operating cam shaft which makes only one rotation in a cycle, and yet secure the rapid actuation of the pilots which is so desirable. Such rapid actuation is possible, because the operating shaft is idle throughout a major portion of the total time, being actuated only briefly at spaced intervals, but running at relatively high speed during a fractional increment of rotation while energized.

The various mechanical elements of the controller will now be described, beginning with the construction and operation of the pilot valves.

The pilot valves

It will be remembered that the purpose of the controller, as here shown, is to control the flow of fluid power from a manifold 22, which is in communication with the fluid power source, to a plurality of outlets 23, each outlet being in communication with its respective working station, and each opening from the manifold to each outlet being controlled by its respective pilot valve. The operations of one such valve will be briefly described, it being understood that all pilot valves operate in similar fashion.

Mounted on the front wall of manifold 22 is a shaft 77 which carries a plurality of rocker arms 78. One end 79 of said rocker arm acts as a cam follower, as will appear, and the other end, on the other side of the pivot, operates the plunger 80 of a three-way valve 25. Valve 25 has an inlet port 84, an outlet port 85 and an exhaust port 86. From an examination of Figs. 1, 2, and 6, it will be apparent that depression of plunger 80 admits fluid pressure from the manifold through port 84 to port 85 and thence to conduit 23 and its working cylinder. When plunger 80 is released, and is biased by spring 85 to exhaust position, the fluid in the working cylinder returns through conduit 23, port 85 and thence through exhaust port 86. The plunger-operating end of rocker arm 78 has an adjustable finger 88 to adjust the sensitivity of valve response. The exhaust port 86 is in communication with an exhaust conduit 86*a*.

The operating cams

I have provided a plurality of operating cams, to suitably operate the pilot valves 25, just described. In juxtaposition to the end 79 of each rocker arm 78, I have disposed a cam disk 93 (Figs. 2 and 6), all said disks being keyed to a cam shaft 26. Each said disk is capable of carrying, on its peripheral edge portion, one or more cam segments 95 which project beyond the circular periphery of the disk, and, during disk rotation as will appear, said segments operatively contact the end 79 of rocker arm 78. Such contact swings arm 78 and depresses plunger 80 so as to admit fluid pressure to a working station for a period of time determined by the circumferential extent of segment 95, and also by the spacing between timing trip fingers 50, as will appear in a later description of the operation of the machine. As best seen in Fig. 2 a plurality of segments 95 may be carried in such close succession that the rocker arm may be operatively engaged, by each segment in turn, for any desired circumferential extent of travel of the cam disk. Specific structural features of this rotary cam arrangement are shown, described, and claimed in my copending application, Serial No. 554,195, filed September 15, 1944, now Patent No. 2,418,757, dated April 8, 1947, but I may here point out that while the segments may be carried by the disks in any suitable way, the cam disk may conveniently comprise two disks of different diameters, a larger disk heretofore designated by reference numeral 93 and a smaller disk 96 in lapped contact with disk 93. The segments 95 are provided with cylindrical projections which fit in apertures 97 in the peripheral edge portion of disk 93. The inner edge of segments 95 rest against the outer edge of disk 96. The segments on each disk are held in place by a spider having a plurality of radial spring fingers 98.

Referring again to Fig. 1, the operating cams are assembled on and keyed to a cam shaft 26 which at its right end is journaled in a bearing 99 on a bracket 100 depending from manifold 22, and at its left end is journaled in a bearing 102 carried on a flange 103 integral with housing 20. Spacing washers 104 are carried on shaft 26, between each adjacent pair of cam disks, and the spring fingered spiders have perforated hub portions to permit their being placed on the shaft next to their respective disks. A nut 105 on the threaded right end of shaft 26 maintains the cam disks in alignment with the valve operating arms.

It will be understood that the shaft 26 makes one rotation per cycle, in intermittent increments, responsive to its drive by motor X soon to be described, and that each plunger valve may be opened and closed once, or a plurality of times during the cycle, depending on the number of segments 95 on the valve's respective cam disk, and the continuous or interrupted circumferential contour of said segments. Any valve may be rendered wholly inoperative during a cycle by removing all segments from its cam disk. Removal or replacement of the segments 95 is an extremely simple matter, by manually raising spider finger 98 and lifting the segment from the disk, and no tools whatever are required.

The indexing motor

The indexing motor X, when energized, drives the cam shaft 26 with its assembled operating cams, to thereby cause operation of the pilot valves and thereby control the operation which is being performed. Motor X is a synchronous motor, geared down through a reduction gear assembly 113. Motor X drives cam shaft 26 through a pinion 114 (Fig. 3) which meshes with a ring gear 115 fixed to a hub portion 117 on the left end of the cam shaft. Motor X is therefore directly coupled to shaft 26, and whenever motor X is energized, shaft 26 rotates in response thereto.

As will be seen, motor X is energized at intervals throughout an operating cycle, such intermittent energizations being the direct result of intermittent closing of the electric circuit to motor X by means now to be described. Such means, constituting the intermediate initiating member between timing cams 49 and motor X, comprises the timing trip assembly and the control wheel.

Timing trip assembly and drive

With particular reference to Figs. 1 and 4, the timing mechanism comprises a plurality of trip fingers 50 fixed on disks 49 carried on the exterior of a hollow cylindrical timing drum 34 and rotatable therewith. The drum 34 is normally rotated by timing motor T through a speed reduction

gearing 35 and a differential bevel gearing referred to generally by reference character D, the differential being located within drum 34. Omitting certain mechanical details which will be apparent to anyone skilled in the art on examining Fig. 4, the drive proceeds from motor T through a pinion 36 on the motor shaft and thence through the gear train 37, 38 and 39 to an output shaft 40 having a driving flange 43 thereon which forms one element of a normally engaged coupling. It will be borne in mind that in the operation of the controller, timer motor T runs continuously. Motor T is a synchronous type motor, and is geared down through the gear train described, so that flange 43 rotates very slowly, making a maximum of only one revolution to a cycle, which may occupy a period of, say, 12 to 60 minutes or longer although the period may conveniently be set to any desired length by changing the gear ratio.

The purpose of the coupling, of course, is to institute or interrupt the drive from motor T to the differential D. The coupling may be of any suitable type, but in the embodiment here shown, it comprises a driving plate consisting of flange 43 heretofore described, a driven plate 44, having a threaded periphery, and a coupling nut 45 having an internally threaded annular flange 46 engageable with the periphery of plate 44. It will be apparent that when coupling nut 45 is tightened, driven plate 44 turns with driving plate 43. A driving pinion 47 of differential D is driven by direct connection with plate 44 through a dog 48 which is keyed, respectively, to said driving pinion and plate 44.

The purpose of differential D is to transmit power and rotary motion from motor T, and also from motor R as will appear, to timing trip assembly 34. Referring now to Figs. 4 and 5, the cylindrical differential housing or drum 34 carries on its outer surface a plurality of timing cam disks 49, each of which has an operating trip finger 50 thereon. The timing cam disks alternate with spacing disks 53. The trip fingers 50 are staggered with respect to each other so as to be spaced both longitudinally and circumferentially for a purpose which will appear. The timing cam assembly at its left end (Fig. 4) abuts a flange 54 of a differential housing hub 55. At its right end it abuts a spacer ring 56, a drum dial 57, and a locking nut 58, which nut has a threaded engagement with the exterior periphery of drum 34. The purpose of nut 58, when engaged, is to lock the several timing cams both with respect to each other and to drum 34 so that the housing and cams are rotatable as a unit. The circumferential position of any or all timing cam disks 49 may be adjusted by loosening nut 58, rotating the disks 49 to the desired positions, and then tightening the nut 58. Adjusting motion of any one timing cam at this time is not transmitted by friction to an adjoining cam since all spacer disks 53 are keyed to the housing 34. Each spacing disk is peripherally graduated in degrees, or any arbitrary numerical system such as hours, minutes, etc., to correspond with, and be alignable with drum dial 57 which is similarly graduated. This facilitates setting of the various timing cams.

The control wheel

In the embodiment of my invention here shown, and with special reference to Figs. 1 and 5, the control wheel 28 includes a ring 118 telescopingly carried on the hub 117 of crank shaft 26, and freely rotatable thereon through an arc of very limited extent between stops, as will appear. This control wheel ring 118 has two parallel, spaced disk flanges 119 and 120 fixed thereon. A lost motion driving connection is provided between the control wheel and shaft 26 as follows: A pin 121 is fixed in hub 117 of shaft 26, and projects into an arcuate slot 123 of flange 119. It will be apparent that the control wheel is freely rotatably rockable on shaft 26 by an amount equivalent to the travel of pin 121 in slot 123, but that the wheel will continue to rotate with shaft 26 as soon as pin 121 engages either end of slot 123, in the direction of pin travel. As will appear, and as illustrated in Fig. 5, flange 119 actuates a switch to energize or deenergize motor X in the following manner: Flange 119 is provided with a series of notches 125 around its periphery which function as cam drops with respect to the operating finger 126 of a cam follower 127 rockably carried on a shaft 128 fixed on bracket flange 103 of the controller housing. The cam follower operates the plunger 129 of a switch S_2, the function of which is to energize and deenergize indexing motor X, as will later more clearly appear in connection with a description of the wiring diagram, Fig. 9.

It is sometimes desirable to prevent operating finger 126 from dropping into one or other of the notches 125 of flange 119. For this purpose, each notch 125 is provided with a pair of spaced apertures 131 adjacent thereto, to accommodate attaching means for a mask 132 which may readily be applied to flange 113, and which, if so applied, bridges the cam drop 125. By this means the cam finger 126 will continue to ride on the periphery of flange 119 past the blanked-off notch, and motor X will not be deenergized at the blanked-off position but will continue to advance shaft 26 until the next unblanked notch arrives under the finger 126.

Flange 120 of the control wheel is provided with at least one notch 133 which acts as a cam drop for a finger (not shown) of a cam follower 134 which operates a plunger 135 of a switch S1. The normal purpose of switch S1 as an element in energizing an operating circuit will appear in conjunction with a description of the complete wiring diagram, and the manner of operation of the control as a unit. Briefly, it serves as a maintaining switch in a circuit for timing motor T.

As has heretofore been indicated, the control wheel serves as an agent intervening between the trip fingers 50 of timing cams 49 and the indexing motor X, so that at pre-ordained intervals the indexing motor may be energized to rotate operating cams 93, and consequently to cause opening and closing movement of the pilot valves 25. This purpose of the control wheel is accomplished as follows:

Extending transversely as bridges across the annular space between control wheel cam flanges 119 and 120 are a plurality of pawls 138 rockably pivoted on shafts 139, and circumferentially spaced and disposed to be engaged, in respective succession, by successive trip fingers 50 of timing cams 49. Each pawl is spring biased to the position shown in Fig. 5. From Fig. 5, it will be apparent that as disk 49 rotates in the direction of the arrow in response to energization of timing motor T, a trip finger 50 engages a pawl 138, and urges the control wheel 28 counterclockwise until the finger 126 of follower 127 rides up onto the circular periphery of cam flange 119. This closes a contact in switch S2, energizing in-

dexing motor X, which thereupon initiates rotary motion of cam shaft 26.

As soon as the pin 121 in the hub 117 of shaft 26 contacts the end of the slot 123 in flange 119, the control wheel drive is taken up by the indexing motor, and rotation of motor X, cam shaft 26, and control wheel 28 continues until the finger 126 of follower 127 drops into the next notch 126 of cam flange 119. At this point the indexing motor X is deenergized at switch S2, and the cam shaft 26 and control wheel 28 stop. The timing motor T, however, continues to rotate, advancing cam disks 49 until the trip finger 50 of the next timing cam 49 advances to contact with the next control wheel pawl 138 which again advances the control wheel through an increment of rotation so as to make the contact in switch S2, repeating this phase of the cycle.

If at any time, such as in the process of adjusting cam disks 49, it becomes necessary to rotate said cam disks in a counterclockwise direction, the spring-biased mounting of a pawl 138 permits it to back off sufficiently to permit passage thereby of a trip finger 50.

The advantage of the interposition of the control wheel in the complete mechanism may here be noted, bearing in mind its loose coupling, through pin 121 and slot 123, to cam shaft 26. If a direct drive between timing cams 49 and the operating cam shaft 26 has been attempted, a considerable operating load on timing motor T would have resulted. With the present construction, timing cams 49 need only exert a gentle touch to rock the control wheel sufficiently on its loose coupling to close switch S2, as explained above, whereupon indexing motor X assumes the burden of driving cam shaft 26. The closing of switch S2 might of course be effected directly by contact with a trip finger 50 so as to energize motor X. The circuit so closed might thereafter be maintained and interrupted by the control wheel disk 119, driven directly by motor X, as shown and described herein.

A third switch, hereinafter identified by reference character S3, is mechanically associated with the train of elements driven by reset motor R. This switch, shown in Figs. 1, 3, and 6, is operated by drum 34 and is fixed adjacent the differential housing hub 55. Said hub carries an annular cam 143 thereon, the cam having a single notch 144 on its cylindrical periphery. This notch is intended to receive the finger 145 of a cam follower 146 which is mounted in lever-like fashion on a pivot 147. An adjustable shoe 148 on follower 146 is in contact with a plunger 149 which operates switch S3. The purpose of switch S3 will later appear, but it may here be mentioned briefly that it assists in making or breaking the circuit to reset motor R at appropriate times.

The differential

As heretofore intimated, the purpose of differential D is to permit simultaneous driving hookup of the timing cam assembly with motors T and R. The differential is of conventional form, and comprises two driving pinions 47 and 67 mounted on a floating shaft 68. As heretofore explained, pinion 47 normally rotates with motor T; pinion 67 rotates with motor R when said motor is intermittently energized as heretofore described. The differential further comprises a plurality of conventional idler pinions 69, freely rotatable on pins 73 fixed in housing 34 and having inner ends supported in a centering block 74. As will be understood by those skilled in the mechanical arts, rotation of either one alone of driving pinions 47 or 67 will cause corresponding rotation of housing 34, and consequently of cam disks 49. Simultaneous rotation of pinions 47 and 67 produces a rotative effect on housing 34 which will be the resultant of the algebraic sum of the directional torques of both said pinions.

The reset motor R

Reset motor R is a synchronous motor hooked up through a speed reduction gearing 75 to drive dog 76, and consequently pinion 67. Its purpose as heretofore indicated is to reset the timing trip assembly 33 to zero or starting position, and for this purpose, it is electrically hooked up suitably, as will appear in describing a complete operation hereinafter, to be energized toward the close of each cycle, and to be deenergized as soon as said zero position is reached. As a result of a proper selection of motor speed and gear ratio, pinion 67 rotates at a high speed relative to pinion 47, and the resultant effect, as applied through the differential, is to rapidly rotate the timing cam assembly to zero position at the close of the cycle. It will be borne in mind, therefore, pending further clarification of the operation, that the timing motor T rotates continuously during operation of the controller, but the reset motor R is energized only intermittently, namely toward the end of each cycle.

Controller operation

The manner of operation of the controller will now be described, reference being had to a schematic showing of the elements of the controller in Fig. 9, the electrical conductors being diagrammatically indicated. For simplicity, in illustrating the functions of the elements, some of said operating elements have been "exploded," and are shown as being driven by belts from their prime movers, although the actual construction as shown in the other drawings is a direct mechanical coupling as already described.

The electric hookup requires five switches, three of which have heretofore been briefly mentioned, but for clarity, all five will be identified, and their function indicated.

Switch S1 is a sensitive switch having an "*a*" position and a "*b*" position. The switch is responsive to the rise and fall of cam follower 134 which rides on the periphery of cam flange 120 and which drops into notch 133 once in each cycle. Cam flange 120 is the right flange on the control wheel, as shown in Fig. 1.

Switch S2 is a sensitive switch having a closed, or "*a*" position, and an open, or "*b*" position. This switch is responsive to the rise and fall of cam follower 127 which rides on the periphery of cam flange 119, and which drops in sequence into a succession of notches 125 on the periphery of said flange to produce the successive stops and starts of index motor X required by the cycle. Cam flange 119 is the left flange on the control wheel. It will be understood that cam flanges 119 and 120, on the control wheel, are driven by index motor X, the control wheel being also momentarily responsive to an initiating impulse from trip fingers 50 on cam disks 49 which are driven by the differential, D, the differential being energizable by either timer motor T or reset motor R.

Switch S3 is a sensitive switch having an "*a*" position, and a "*b*" position. The switch is responsive to the rise and fall of cam follower 146 which rides on the periphery of cam 143, and

which drops into notch 144 once in each cycle. Cam 143 is the annular cam carried on differential hub 55.

Switch S4 is a push button starting switch located at any convenient place on the controller housing, and is momentarily depressed manually, as will appear, to energize operating circuits, including a maintaining circuit which thereupon permits release of switch S4.

Switch S5 is any conventional line switch which may be closed at the beginning of an operating period after a shut down. Opening this switch deenergizes the whole electrical system of the controller, and closing it permits controller operation.

Motor T normally advances the timing trip assembly 33 and motor R resets said timing trip assembly. Motor X intermittently rotates cam shaft 26 which carries the operating cams for the pilot valves.

The position of all switches as shown in Fig. 9 is that normally occupied by them at the start of the day's operations.

To institute an operation, line switch S5 is closed and push button switch S4 is depressed. Motors T and X are thereupon energized, through the following circuits, and with the following results:

Motor T is enerized as follows: from L2 through switch S5, conductor 153, switch S1 in "b" position, conductor 154, switch S3 in "a" position, conductor 155, push button S4, conductors 156 and 157, windings of motor T, conductors 158, 159, and 160 to switch S5 and thence to L1. Simultaneously motor X is energized in a shunt circuit, from points 164 and 165 in circuit just described, as follows: from point 164 (near push button switch S4) through conductors 166 and 167, switch S2 in "a" position, conductor 168 windings of motor X, and conductor 169 to point 165. Motors T and X thereupon begin to rotate.

Timer motor T, through differential drive D, institutes slow rotary motion of timing trip assembly 33 and reset cam 143. Indexing motor X while energized takes up the drive of cam shaft 26 and of cams 119 and 120 on the control wheel.

Almost immediately the shunt circuit energizing motor X is broken, as will now appear. The first increment of rotary motion of cam 120 raises follower 134 towards the circular periphery of the cam 120 where it will remain throughout a complete cycle. This moves switch S1 to contact "a." Immediately thereafter, follower 127 drops into the first notch 125 of cam 119 causing switch S2 to break contact at "a." This movement of switch S2 breaks the shunt circuit for motor X which was described above. Motor X is therefore temporarily deenergized.

As soon as switch S1 is moved to "a" position by cam 120, a maintaining circuit is set up for motor T, permitting continuous operation of motor T for a complete cycle, and push button S4 may be released. The maintaining circuit proceeds as follows: from L2 through switch S5, conductor 153, switch S1 in "a" position, conductors 173, 166, and 157, windings of motor T, conductors 158, 159, and 160, switch S5 to L1. This maintaining circuit remains closed throughout the cycle, switch S1 remaining in "a" position, and timer motor T runs continuously, advancing timing trips 50 to engage controller wheel pawls 138 with the following result.

One of the peripherally spaced trip fingers 50 on a cam disk 49 engages one of the controller wheel pawls 138 (Fig. 5) causing an increment of free advance of the control wheel sufficient to raise follower 127 out of its notch 125, thereby moving switch S2 to "a" position. This immediately energizes the shunt circuit above described for motor X which takes up the drive of the control wheel, and of cams 119 and 120, and which likewise institutes rotation of cam shaft 26. This status is maintained until follower 127 drops into the next notch of cam 119, again breaking the shunt circuit to motor X.

In the increment of movement of cam shaft 26 produced by the temporary energizing of motor X as described, one or more segments 95 on operating cams 93 engage, respectively, one or more rocker arms 78, to cause an opening movement in one or more respective pilot valves 25, permitting fluid pressure to pass to one or more conduits 23. The circumferential extent of operating cam segments 95 (Figs. 2 and 3) and the spacing between trip fingers 50 determine the period within which valve 83 remains open.

It will be understood that since timer motor T continues to run, the next trip finger 50 will engage the next pawl 138, again advancing the control wheel, and again, through switch S2, energizing motor X to produce another increment of motion of cam shaft 26 with consequent possible operation of one or more pilot valves 25. Continuous operation of motor T produces continuous advance of cam 143, and intermittent operation of motor X produces incremental advances of cams 119 and 120.

As will quickly appear, the function of cam 143 is to maintain switch S3 in "b" position through an operating cycle, since in this position the circuit to reset motor R is in condition to be completed as soon as cam 120 permits switch S1 to drop to "b" position. It is therefore desirable that cam 120 have its notch 133 disposed at a circumferential position, synchronized with cam 119 that little time is lost between the end of a complete cycle of operations and the arrival of notch 133 under follower 134 at switch S1.

At this point, follower 134 drops, and switch S1 moves to "b" position. The circuits to motors T and X are broken at "a" of switch S1; motors T and X are deenergized and reset motor R is immediately energized as follows: from line L2 through switch S5, conductor 153, switch S1 in "b" position, conductor 154, switch S3 in "b" position, conductor 177, windings of motor R, conductors 178, 159, and 160, switch S5 to L1. Reset motor R is geared to produce a relatively considerably higher speed than either motors T or X, and through differential D it rapidly returns cam 143 to the point where follower 146 drops in notch 144 to move switch S3 to "a" position, deenergizing the last defined circiut including motor R. This brings all elements to the position shown in Fig. 9, in condition to begin the next cycle, and repeat the process already described. Motors T and X will again be energized for the next cycle by depressing push button switch S4.

Setting the timing trips and dial

As heretofore indicated, the timing cam assembly 33 is provided with a graduated dial 57 whereby the operator can determine, at any particular time, how much of the cycle has elapsed and how much time remains before completion of said cycle, the dial of course turns with the timing cam disks and trips during the cycle, being clamped thereto by dial nut 53. The dial may conveniently be circumferentially graduated

in minutes and fractions thereof, corresponding to time elapsed during the cycle.

As best seen in Fig. 10, the central circular opening of dial **57** is provided with an arcuate enlargement **183**, which is disposed to serve as a track for a pin **184** carried by ring **56**. Ring **56** and cam spacers **53** are keyed to drum **34**. It is apparent that when coupling nut **46** is tightened, it prevents free rotation of the timing trip assembly, the spacers **53**, and the ring **56**. The dial **57** may however be swung back and forth through a 90 degree arc so long as dial nut **584** is slacked off. The purpose of this 90 degree swing of the dial will soon appear.

I have provided a stationary pointer **185**, carried by motor bracket **186**, for use as a point of reference in reading dial **57**, or in setting trip fingers **50**. This pointer is placed at a convenient viewing location, namely directly in front as shown in Fig. 1, yet the actual operating point of the cycle is being determined by the one of the trip fingers **50** at the top of the timing drum assembly, which finger is either in contact with, or about to contact a control wheel pawl. This actual operating point is spaced 90 degrees from pointer **185**. It is accordingly desirable that when the operator reads the dial at the pointer during operation, his reading should tell him the situation existing at a point 90 degrees away.

In setting the dial and cams the operator therefore proceeds as follows: Coupling nut **46** and dial nut **58** are slacked off, leaving the timing trip assembly **33** free to rotate. The dial **57** is also free to rotate, and its zero point is placed in alignment with the first trip finger **50**, both the dial zero point and the said trip finger being aligned with pointer **185**. The other fingers **50** are staggered circumferentially at properly spaced points to successively energize the indexing motor X through operation of the controller wheel. The whole assembly is now swung to a position where the first operation finger **50** is adjacent the bottom control wheel pawl, and the coupling nut **46** is tightened.

It will now be observed that the dial zero point will not register with the dial indicator, but will be on top of the assembly, immediately beneath the control wheel. By slacking off the dial nut **58**, the dial can be rotated forwardly and downwardly through 90 degrees by the pin and slot connection already described, bringing the dial zero point under the indicating finger, after which the dial nut is again tightened. As a result, the reading at said finger registers the actual situation 90 degrees away, and accurately tells the elapsed time of the cycle.

Manual operation of pilot valves

At any point in the cycle it may be desirable to admit a non-scheduled flow of pressure to any one of the power cylinders serviced by its respective conduit **23** and pilot valve **25**. I have provided a manual control for this purpose.

Referring to Fig. 6, the controller housing **29** is illustrated with a front cover **186***a* in place. The cover carries a row of spaced push buttons **187**, only one being shown in Fig. 6. The push button has a plunger extension **188** passing through a boss **189** carried by cover **186**. Each said push button is in registry with the valve-operating end of a rocker arm **70**, so that depression of a button **187** opens a pilot valve and admits pressure to a cylinder, regardless of the position of the operating cam which automatically operates the valve at preset intervals.

It might be mentioned here that a plunger-operated switch **190** having an operating plunger **191** (Fig. 8) may be substituted for a pilot valve **83** where it is desired to use electricity rather than fluid power as a source of energy.

What I claim is:

1. Control mechanism for operating a plurality of control devices, comprising a rotatable operating member provided with actuators distributed around its axis and arranged during several steps of one complete rotation to actuate said devices in sequence to complete a cycle of operations controlled thereby, an indexing motor for intermittently rotating said member rapidly by successive steps, and a rotatable trip shaft having a series of trips distributed around its axis each arranged during shaft rotation to initiate operation of said indexing motor, and timing motor means for rotating said shaft continuously during each cycle, and a reset motor for rapidly rotating said trip shaft to restore it to initial position.

2. Control mechanism for operating a plurality of control devices, comprising a rotatable operating member provided with actuators distributed around its axis and arranged during several steps of one complete rotation to actuate said devices in sequence to complete a cycle of operations controlled thereby, an indexing motor for intermittently rotating said member rapidly by successive steps, and a rotatable trip shaft having a series of trips distributed around its axis each arranged during shaft rotation to initiate operation of said indexing motor, and timing motor means for rotating said shaft continuously during each cycle, and a reset motor for rapidly rotating said trip shaft to restore it to initial position and differential mechanism connecting said timing and reset motors to said trip shaft for operation by either thereof.

3. Control mechanism for operating a plurality of control devices, comprising a rotatable operating member provided with actuators distributed around its axis and arranged during several steps of one complete rotation to actuate said devices in sequence to complete a cycle of operations controlled thereby, an indexing motor for intermittently rotating said member rapidly by successive steps, and a rotatable trip shaft having a series of trips distributed around its axis each arranged during shaft rotation to initiate operation of said indexing motor, and timing motor means for rotating said shaft continuously during each cycle, and a reset motor for rapidly rotating said trip shaft to restore it to initial position and differential mechanism connecting said timing and reset motors to said trip shaft for operation by either thereof, and means preventing operation of either of said timing and reset motors when the other is operating.

4. Control mechanism for operating a plurality of control devices, comprising a rotatable operating shaft provided with actuators distributed around its axis and arranged during several steps of one complete rotation to actuate said devices in sequence to complete a cycle of operations controlled thereby, an indexing motor coupled to said operating shaft for rotating said operating shaft rapidly while said indexing motor is energized, a switch in the electrical circuit of said indexing motor, a control member having a lost motion connection with said operating shaft, said control member being operatively engageable with said switch, a rotatable trip shaft having a series of trips distributed around its axis each

arranged during trip shaft rotation to temporarily engage said control member so as to operate said switch and initiate operation of said indexing motor, and a timing motor for rotating said trip shaft.

5. Control mechanism for operating a plurality of control devices, comprising a rotatable operating shaft provided with actuators distributed around its axis and arranged during several steps of one complete rotation to actuate said devices in sequence to complete a cycle of operations controlled thereby, an indexing motor coupled to said operating shaft for rotating said operating shaft rapidly while said indexing motor is energized, a switch in the electrical circuit of said indexing motor, a control member having a lost motion connection with said operating shaft, said control member being operatively engageable with said switch, a rotatable trip shaft having a series of trips distributed around its axis each arranged during trip shaft rotation to temporarily engage said control member so as to operate said switch and initiate operation of said indexing motor, and a timing motor for rotating said trip shaft, and a reset motor for rapidly rotating said trip shaft to initial position at the completion of a cycle of operations.

6. Control mechanism for operating a plurality of control devices, comprising a rotatable operating shaft provided with actuators distributed around its axis and arranged during several steps of one complete rotation to actuate said devices

in sequence to complete a cycle of operations controlled thereby, an indexing motor coupled to said operating shaft for rotating said operating shaft rapidly while said indexing motor is energized, a switch in the electrical circuit of said indexing motor, a control member having a lost motion connection with said operating shaft, said control member being operatively engageable with said switch, a rotatable trip shaft having a series of trips distributed around its axis each arranged during trip shaft rotation to temporarily engage said control member so as to operate said switch and initiate operation of said indexing motor, and a timing motor for rotating said trip shaft, said control member being responsive to operation of said operating shaft when said lost motion is taken up so as to rotate with said shaft, cause opening of said switch, and deenergize said indexing motor.

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