July 19, 1960 H. F. MASON 2,945,969

ROTARY SWITCHING APPARATUS

Filed Feb. 3, 1958 5 Sheets-Sheet 1

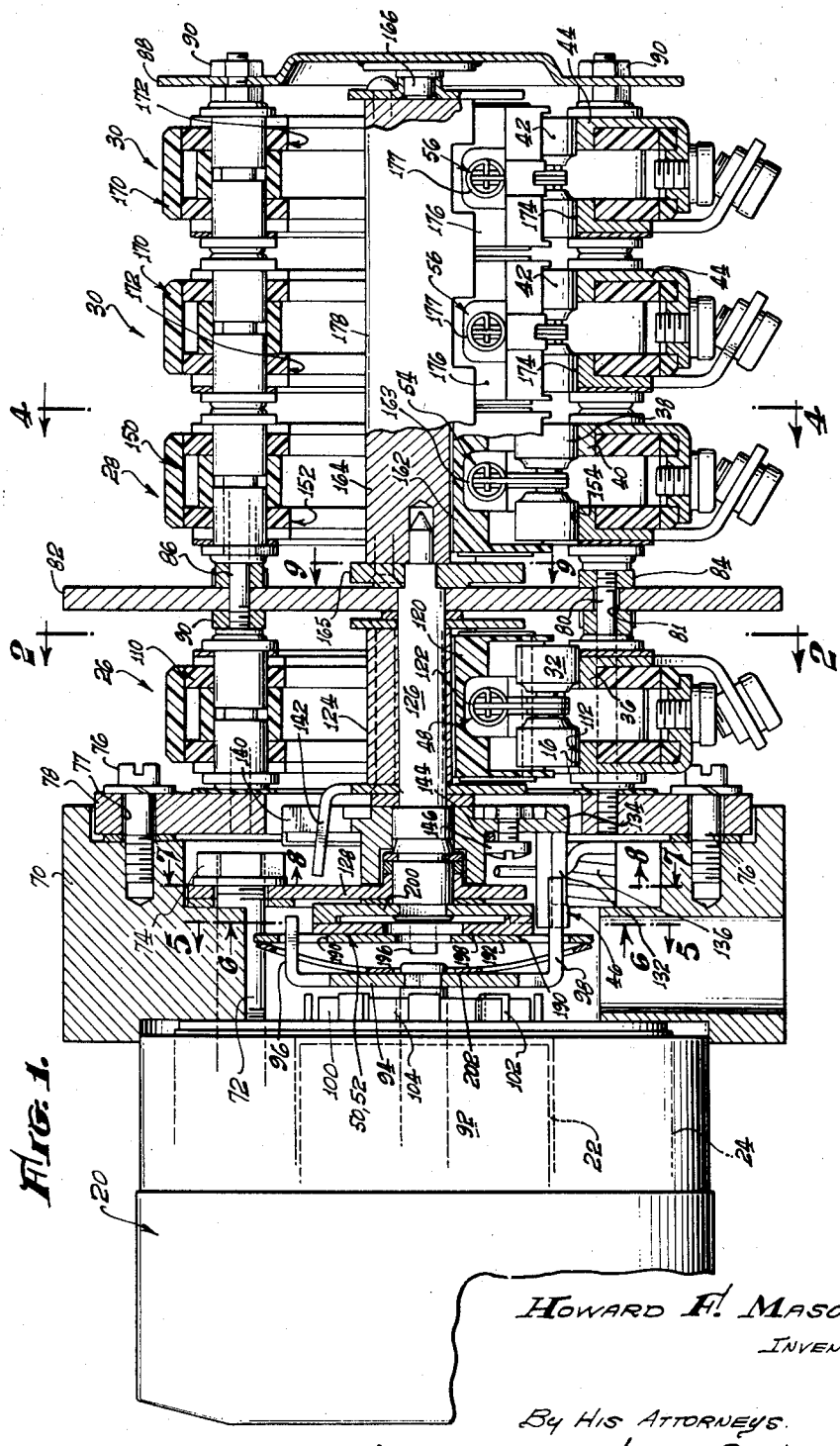


FIG. 1.

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July 19, 1960 H. F. MASON 2,945,969

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Filed Feb. 3, 1958 5 Sheets-Sheet 2

FIG. 2.

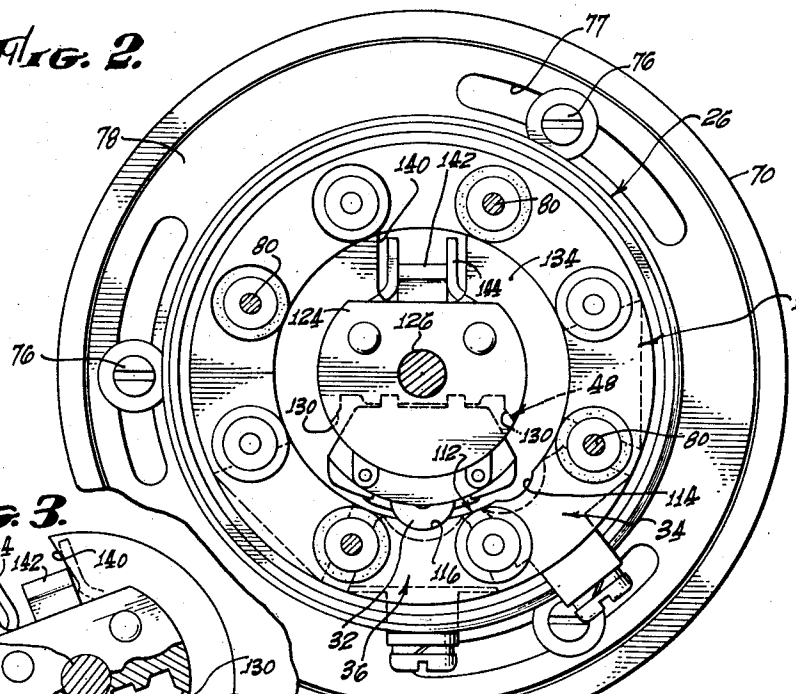


FIG. 3.

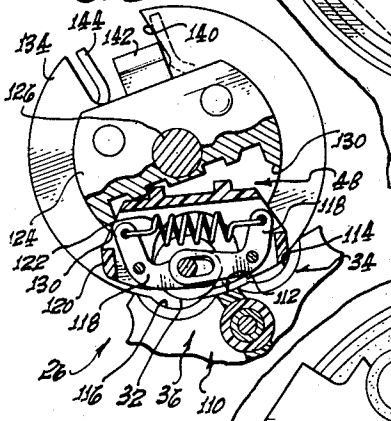
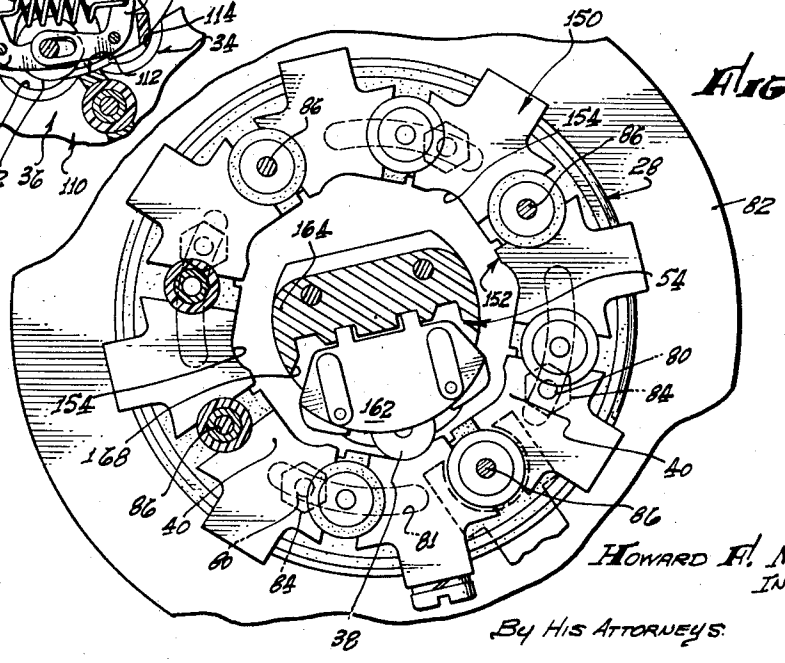


FIG. 4.



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July 19, 1960 H. F. MASON 2,945,969

ROTARY SWITCHING APPARATUS

Filed Feb. 3, 1958 5 Sheets-Sheet 3

FIG. 5.

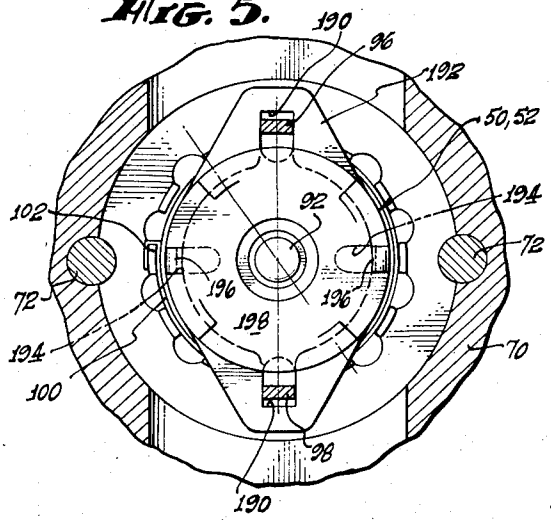


FIG. 6.

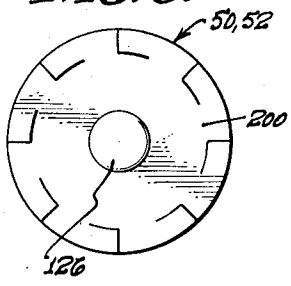


FIG. 7.

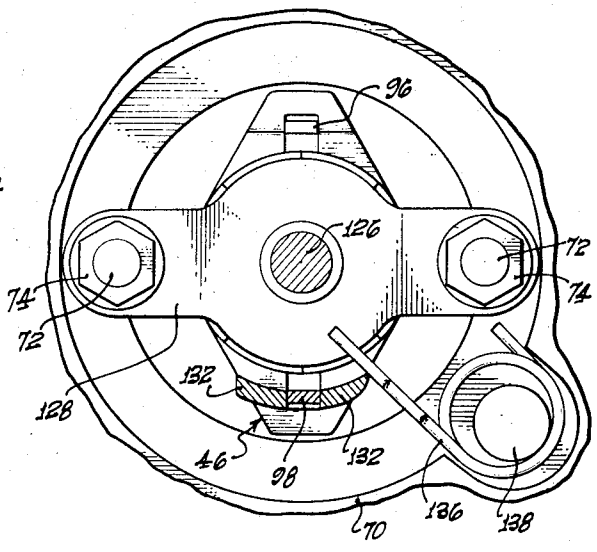


FIG. 8.

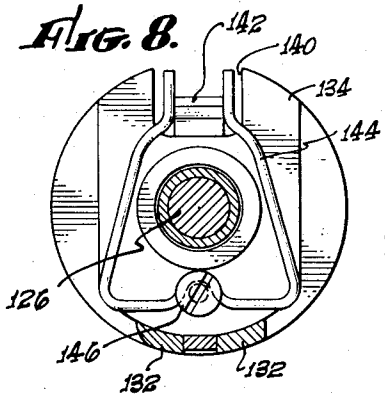
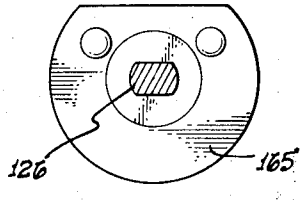


FIG. 9.



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July 19, 1960 H. F. MASON 2,945,969

ROTARY SWITCHING APPARATUS

Filed Feb. 3, 1958 5 Sheets-Sheet 4

FIG. 10.

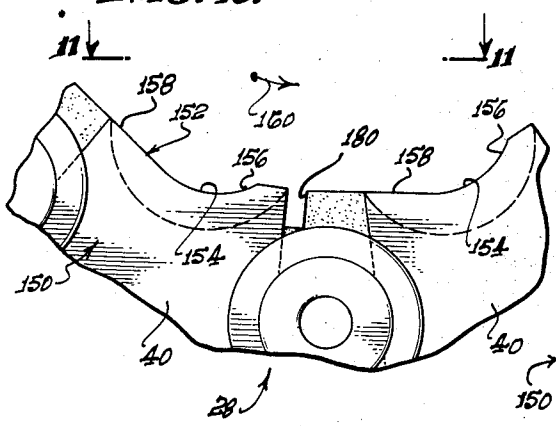


FIG. 11.

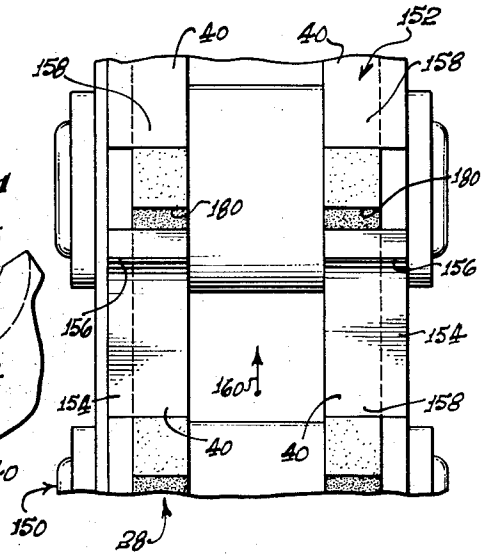
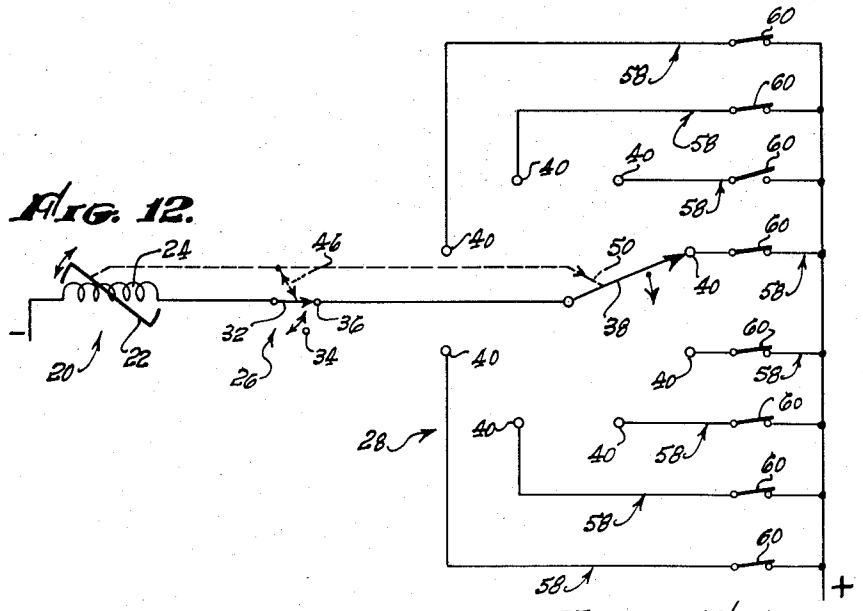


FIG. 12.



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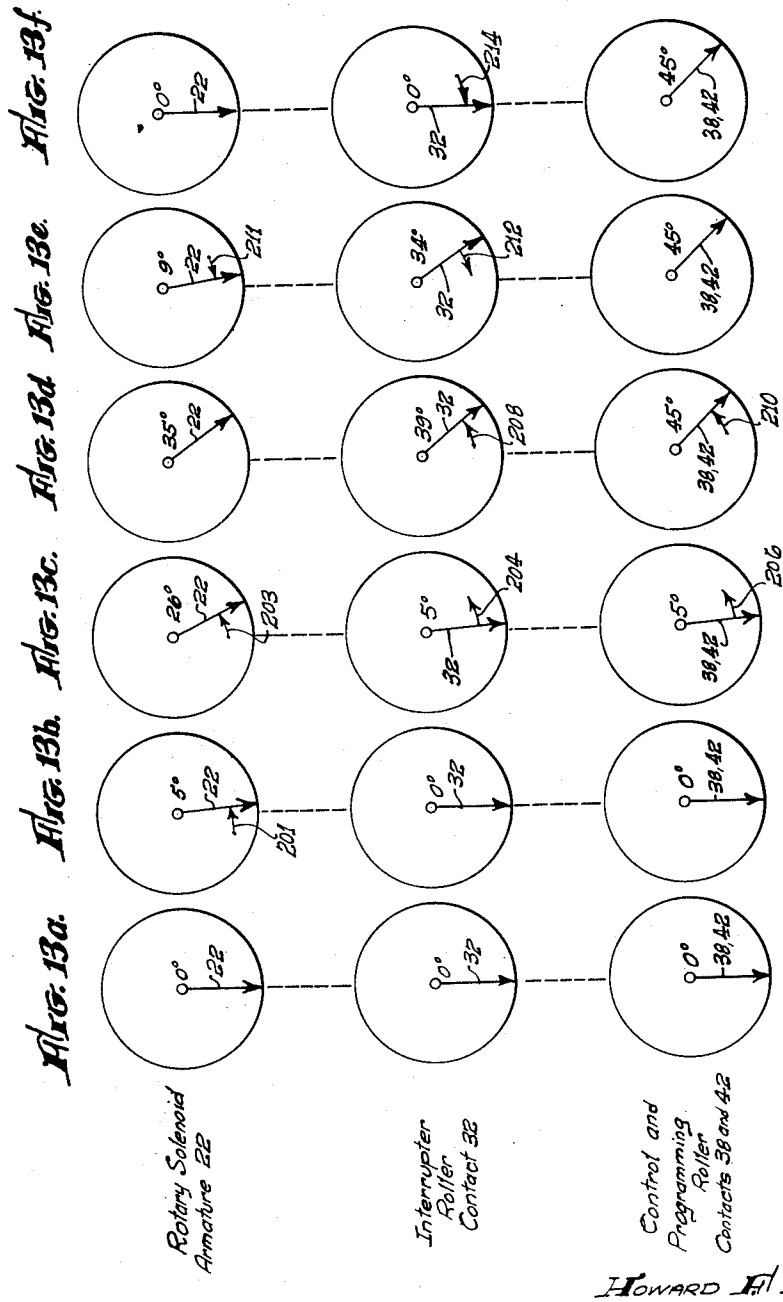
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July 19, 1960 H. F. MASON 2,945,969

ROTARY SWITCHING APPARATUS

Filed Feb. 3, 1958 5 Sheets-Sheet 5



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United States Patent Office 2,945,969 Patented July 19, 1960

2,945,969

ROTARY SWITCHING APPARATUS

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Filed Feb. 3, 1958, Ser. No. 712,785

16 Claims. (Cl. 310—37)

The present invention relates in general to programmers and, more particularly, to an apparatus which performs various external controlling functions in response to the application of control signals thereto from external signal sources.

Still more particularly, the invention relates to a programmer capable of scanning a plurality of control circuits seriatim in a step-by-step manner in search of one which is open and capable of controlling corresponding programming circuits, the programmer at any instant controlling the programming circuit which corresponds to a particular open control circuit it has located as the result of the scanning operation. Thus, the invention constantly seeks an open control circuit and, when it finds one, it controls the corresponding programming circuit.

A general object of the invention is to provide a programmer of the foregoing nature which includes a rotary solenoid, a rotary interrupter switch coaxial with and electrically connected in series with the rotary solenoid, bidirectional coupling means mechanically connecting the interrupter switch to the rotary solenoid so that the latter drives the interrupter switch in both directions, a rotary, multi-position control switch coaxial with the rotary solenoid and the interrupter switch and electrically connected in series therewith, unidirectional coupling means mechanically connecting the control switch to the rotary solenoid so that the latter drives the control switch in one direction only, at least one rotary, multi-position programming switch coaxial with the rotary solenoid, the interrupter switch and the control switch and having programming positions which correspond to the control positions of the control switch, and unidirectional coupling means mechanically connecting the programming switch to the rotary solenoid so that the latter drives the programming switch in one direction only.

With the foregoing construction, the interrupter switch oscillates with the rotary solenoid between open and closed positions, while the control and programming switches rotate through their respective ranges of control and programming positions in one direction in a step-by-step manner. Since the rotary solenoid and the interrupter and control switches are electrically connected in series, the rotary solenoid is energized each time it returns the interrupter switch to its closed position as long as the control switch is in a closed control position. Thus, the rotary solenoid steps continuously until the control switch finds an open control position, i.e., until the control switch finds an open control circuit, whereupon the rotary solenoid stops stepping. Under such conditions, the programming switch controls, and preferably closes, a programming circuit corresponding to the open control position or control circuit located by the control switch. This state of affairs persists until such time as the control circuit in which the control switch is connected is closed by some external means, whereupon the rotary solenoid again steps until the control switch finds another open control circuit.

An important object of the invention is to provide a

device which includes a rotary solenoid and a rotary switch mechanically connected together by a coupling means which incorporates a resilient lost-motion connection permitting limited rotational movement of the rotary solenoid relative to the rotary switch and capable of storing energy therein. With this construction, when the rotary solenoid rotates, it rotates relative to the rotary switch until the range of lost motion provided by the lost-motion connection is taken up, whereupon the rotary solenoid forces the rotary switch out of the position in which it is disposed, the energy stored in the lost-motion connection thereafter carrying the rotary switch to its next position. Another object of the invention in this connection is to provide a device wherein the rotary switch driven by the rotary solenoid includes a movable contact, preferably a roller contact, which is pivotable or rotatable about the axis of the rotary switch through at least a part of a revolution and which is receivable in recesses in circumferentially spaced stationary contacts disposed on an arcuate contact path, the movable contact being resiliently biased into engagement with the contact path.

With the foregoing construction, the movable contact of the rotary switch is forced out of the recess in which it is disposed when the end of the range of lost motion between the rotary switch and the rotary solenoid is reached, whereupon the energy stored in the lost-motion connection causes the movable contact to jump to the next recess independently of the rotary solenoid, the movable contact dropping into the next recess and being held therein by the resilient means which biases it toward the contact path. Since the movable contact negotiates the distance between recesses independently of the rotary solenoid and solely under the influence of the energy stored in the lost-motion connection between it and the rotary solenoid, the rotary switch steps in a positive and reliable manner and cannot overshoot, which is an important feature of the invention.

The foregoing may be achieved by utilizing as the rotary switch one of the rotary switches disclosed in my United States Patents Nos. 2,831,073, 2,831,081 and 2,831,082, all granted April 15, 1958. In each of the rotary switches disclosed in these patents, the aforementioned resilient lost-motion connection and the resilient means for biasing the movable contact into engagement with the contact path are incorporated directly therein. Consequently, in the present invention, the rotary solenoid may be coupled directly to one of the rotary switches of these patents to achieve the results hereinbefore discussed.

Another object of the invention is to provide a device including a rotary switch driven by a rotary solenoid wherein the stored-energy jump of the rotary switch exceeds the angular stroke of the rotary solenoid, which permits a reduction in the weight and current requirements of the rotary solenoid.

An important object of the invention is to provide a programmer wherein each of the interrupter, control and programming switches has the characteristics hereinbefore discussed and wherein the rotatable contacts of these switches break from their respective recesses at the same instant, this being accomplished by providing all of the movable contacts with substantially the same degrees of lost motion relative to the rotary solenoid and providing the lost-motion connections with substantially equal energy storing capacities. Also, the movable contacts of the control and programming switches are preferably structurally interconnected to insure that they break from their respective recesses at the same instant and to insure that they enter the next recesses at the same instant, thereby assuring simultaneous performance of the control and programming operations.

An important advantage of utilizing as the interrupter switch a rotary switch having a resilient lost-motion connection between the rotary solenoid and the interrupter contact of the nature hereinbefore described is that the lost-motion connection causes the interrupter contact to lag the rotary solenoid. Consequently, as the rotary solenoid returns to its initial position after having been energized to move the interrupter contact to its open position, the interrupter contact remains in its open position until the rotary solenoid has returned substantially to its initial position, due to the lost motion in the coupling means between the interrupter switch and the rotary solenoid. This insures that the rotary solenoid will not be re-energized until it has returned to its initial position, which is an important feature of the invention.

Another important feature of the foregoing structure is that the lost-motion connection between the interrupter switch and the rotary solenoid permits the rotary solenoid to substantially complete its energized, advance stroke from its initial position to its advanced position before the interrupter contact leaves its closed position, the energy stored in the lost-motion connection between the interrupter contact and the rotary solenoid then carrying the interrupter contact to its open position while the inertia of the rotary solenoid and the decaying field therein carry the rotary solenoid to the end of its advance stroke. By the time the interrupter contact reaches its open position, the rotary solenoid has reached its advanced position and is ready to execute its return stroke to its initial position, such return stroke being produced by spring means, or the like. The interrupter contact then remains in its open position until the rotary solenoid has returned substantially to its initial position, this lag, as hereinbefore stated, preventing the interrupter contact from returning to its closed position until the rotary solenoid has returned to its initial position so that premature re-energization of the rotary solenoid is prevented.

Since the rotary control and programming switches are unidirectional, each of the recesses in the contact paths of these switches is, in effect, one-sided, the other side of each recess being defined by a surface which extends smoothly substantially from the preceding recess to the bottom of the recess being considered. In other words, one side of each recess is defined by a generally radial shoulder and the other side of such recess is defined by a surface which extends smoothly substantially from the generally radial shoulder of the preceding recess to the bottom of the recess in question. The movable or rotatable contact of each of the control and programming switches, which movable or rotatable contact is preferably a roller contact, moves in a direction such that it travels downwardly from the generally radial shoulder of the preceding recess to the bottom of and into engagement with the generally radial shoulder of the next recess. Thus, in effect, in moving from one recess to the next, the movable contact of each of the control and programming switches moves down an inclined surface to the bottom of the next recess. This contact-path construction insures that the movable contacts of the control and programming switches will always move all the way to their next positions upon each energization of the rotary solenoid, which is an important feature.

Another object of the invention is to provide narrow gaps in the contact paths of the control and programming switches adjacent the trailing sides of the recesses therein, these gaps being narrow as compared to the recesses. Since the gaps mentioned are adjacent the trailing sides of the recesses, the energies stored in the resilient lost-motion connections between the rotatable contacts of the control and programming switches and the rotary solenoid are near maximum values when the movable contacts encounter the gaps. Consequently, the movable contacts will pass over such gaps without tending to drop into them under the influence of the resilient means biasing the contacts into engagement with the contact paths. The gaps just considered perform an extremely important function in that they prevent the formation of conductive films between stationary contacts due to tracking of metal over the insulating segments of the contact path between the stationary contacts.

The foregoing objects, advantages, features and results of the present invention, together with various other objects, advantages, features and results thereof which will be evident to those skilled in the art in the light of this disclosure, may be attained with the exemplary embodiment of the invention described in detail hereinafter and illustrated in the accompanying drawings, in which:

Fig. 1 is a longitudinal sectional view of a programmer which embodies the invention;

Fig. 2 is a transverse sectional view taken along the arrowed line **2—2** of Fig. 1;

Fig. 3 is a fragmentary transverse sectional view duplicating a portion of Fig. 2 with various components in operating positions differing from those shown in Fig. 2;

Fig. 4 is a transverse sectional view taken along the arrowed line **4—4** of Fig. 1;

Fig. 5 is a transverse sectional view taken along the arrowed line **5—5** of Fig. 1;

Fig. 6 is a fragmentary transverse sectional view taken along the arrowed line **6—6** of Fig. 1;

Fig. 7 is a transverse sectional view taken along the arrowed line **7—7** of Fig. 1;

Fig. 8 is a transverse sectional view taken along the arrowed line **8—8** of Fig. 1;

Fig. 9 is a transverse sectional view taken along the arrowed line **9—9** of Fig. 1;

Fig. 10 is an enlarged, fragmentary view duplicating a portion of Fig. 4 on an enlarged scale;

Fig. 11 is an elevational view taken along the arrowed line **11—11** of Fig. 10;

Fig. 12 is a simplified wiring diagram of the programmer of the invention; and

Figs. 13*a* to 13*f* are diagrammatic views illustrating the operation of the programmer of the invention.

Referring first to Figs. 1 and 12 of the drawings for a general description of the structure and operation of the programmer of the invention, such programmer includes and is actuated by a rotary solenoid **20** of conventional construction which includes an oscillatory armature **22** acting as a drive means for the programmer and a stationary coil **24** constituting an electrically energizable means for moving the armature **22** in one direction. The coil **24**, when energized, produces the advance or forward stroke of the armature **22**, the return stroke of the armature from its advanced position to its initial position being effected in a manner to be described.

Axially aligned with the rotary selenoid **20** are a rotary interrupter switch **26**, a rotary control switch **28** and one or more rotary programming switches **30**, two programming switches being shown. Referring to Fig. 12, the interrupter switch **26** includes a movable contact **32** which oscillates between open and closed positions **34** and **36**, the open and closed positions **34** and **36** being represented by stationary contacts identified by the same reference numerals for convenience, although it will be understood that the stationary contact **34** corresponding to the open position of the interrupter switch is not actually an electrical contact.

The control switch **28** includes a movable contact **38** engageable with circumferentially spaced stationary contacts **40** seriatim. The programming switches **30** include movable contacts **42** engageable with circumferentially spaced stationary contacts **44** seriatim, the programming switches not being shown in Fig. 12 of the drawings.

As will be apparent from Fig. 1 of the drawings, the movable contacts **32**, **38** and **42** are roller contacts and the stationary contacts **36**, **40** and **44** comprise pairs of

contact elements which are adapted to be bridged by the respective roller contacts. However, as a matter of convenience, the movable contacts 32 and 38 and the stationary contacts 36 and 40 are shown as simple contacts in Fig. 12 of the drawings.

The interrupter switch 26, or more accurately, the movable contact 32 of the interrupter switch, is mechanically connected to the rotary solenoid 20, i.e., to the armature 22 of the rotary solenoid, by a bidirectional coupling means 46 which includes a resilient lost-motion connection 48. The control switch 28 and the programming switches 30 are mechanically connected to the rotary solenoid 20 by unidirectional coupling means 50 and 52 respectively including resilient lost-motion connections 54 and 56, the unidirectional coupling means 50 and 52 including various common components as will appear hereinafter. The bidirectional coupling means 46 between the rotary solenoid 20 and the interrupter switch 26 and the unidirectional coupling means 50 between the control switch 28 and the rotary solenoid are shown diagrammatically in Fig. 12 of the drawings.

The rotary solenoid 20, the interrupter switch 26 and the control switch 28 are electrically connected in series so that the solenoid is energizable only when the interrupter switch and the control switch are closed. This series relationship between the rotary solenoid 20, the interrupter switch 26 and the control switch 28 is shown diagrammatically in Fig. 12 of the drawings as a matter of convenience, although, as hereinbefore discussed, the movable contacts 32 and 38 are actually roller contacts adapted to bridge pairs of contact elements forming the stationary contacts 36 and 40 so that the actual circuitry will differ correspondingly from that shown in Fig. 12 in a manner obvious to those skilled in the art.

The stationary control contacts 40 of the control switch 28 are connected in control circuits 58 which include regulating switches 60 operable by any desired regulating or control means external to the programmer of the invention. Such external regulating means opens or closes the regulating switches 60 in accordance with variations in external conditions to which the programmer of the invention responds in a manner which will now be described.

As will be apparent from Fig. 12 of the drawings, when the interrupter switch 26 is in its closed position 36 and when the movable contact 38 of the control switch 28 is in engagement with a stationary contact 40 having a closed regulating switch 60 in circuit therewith, the rotary solenoid 20 is energized and, acting through the bidirectional coupling means 46 and the unidirectional coupling means 50, opens the interrupter switch and advances the movable control contact 38 one step. Thereafter, the rotary solenoid 20 returns to its initial position and, through the bidirectional coupling means 46, returns the interrupter switch 26 to its closed position, the movable control contact 38 remaining in the position to which it has been advanced. If the movable control contact 38 is now in engagement with a stationary control contact 40 having an open regulating switch 60 in circuit therewith, the rotary solenoid 20 will not be reenergized. However, if the regulating switch 60 in circuit with the movable control contact 38 is closed, the rotary solenoid will be reenergized, whereupon the foregoing sequence of events will be repeated.

Thus, the rotary solenoid 20 oscillates the interrupter switch 26 and advances the control switch 28 until the movable control contact 38 locates a control circuit 58 which is open. In other words, the rotary solenoid 20 steps until an open control circuit 58 is located, whereupon the solenoid stops stepping until such time as the open control circuit 58 is subsequently closed.

As will be explained in more detail hereinafter, the programming switches 30 have programming positions corresponding to the control position of the control switch 28, this preferably being accomplished by locating the stationary programming contacts 44 in axial alignment with the stationary control contacts 40, respectively. Thus, whenever the rotary solenoid 20 stops stepping after having located an open control circuit 58, the movable programming contacts 42 engage the corresponding stationary programming contacts 44 to close corresponding programming circuits, not shown. These programming circuits may include means for varying any desired conditions in response to the condition variation which originally caused the opening of the open control circuit 58 located by the programmer of the invention.

With the foregoing general description of the construction and operation of the programmer of the invention as background, the structure of the programmer will now be considered in more detail, taking up first the structural relationship between the rotary solenoid 20, the interrupter switch 26, the control switch 28 and the programming switches 30. These components of the programmer are all carried by a main mounting head 70 by means of which the entire device may be mounted on a suitable supporting structure. The rotary solenoid 20 is connected directly to the mounting head 70 by studs 72 threaded into the housing of the rotary solenoid and provided with nuts 74. Connected to the mounting head 70 by screws 76 is a mounting plate 78 having studs 80 threaded thereinto, these studs extending through and carrying the interrupter switch 26 and a second mounting plate 82. The interrupter switch 26 and the mounting plate 82 are retained on the studs 80 by nuts 84 threaded thereon. Connected to the mounting plate 82 by bolts 86 are the control switch 28, the programming switches 30 and an end plate 88, the bolts 86 having nuts 90 threaded on the ends thereof. The screws 76 project through circumferentially extending slots 77 in the mounting plate 78 to provide for angular adjustment of the interrupter switch 26 relative to the rotary solenoid 20. Similarly, the studs 80 project through circumferentially extending slots 81 in the mounting plate 82 so that the control and programming switches 28 and 30, which are carried by the mounting plate 82, may be adjusted angularly relative to the interrupter switch 26 and the rotary solenoid 20. These angular adjustments permit establishing the proper angular relationships between the rotary solenoid 20, the interrupter switch 26, the control switch 28 and the programming switches 30 upon assembly, these angular relationships being considered in more detail hereinafter.

As best shown in Figs. 1 and 5 of the drawings, the oscillatory armature 22 of the rotary solenoid 20 includes a shaft 92 which projects into the mounting head 70 and which has fixed thereon a yoke 94 provided with short and long arms 96 and 98, the yoke forming part of the coupling means 46, 50 and 52 as will be described hereinafter. The armature 22 of the rotary solenoid 20 is advanced by energization of the coil 24, and is returned to its initial position in part by a spiral return spring 100 having an end hooked around a tab 102 on the solenoid housing and having its other end anchored to the armature at 104. The action of the spiral return spring 100 is supplemented by another return spring to be described.

The interrupter, control and programming switches 26, 28, and 30 are similar to the switches disclosed in my aforementioned Patent No. 2,831,073 in the particular construction illustrated. Consequently, the interrupter, control and programming switches 26, 28 and 30 will be described herein only to the extent necessary to provide an adequate disclosure of the programmer of the invention, reference being made to the patent just mentioned for a complete disclosure of these switches.

Considering the interrupter switch 26, it includes a stator 110 mounted on the studs 80 and providing an arcuate contact path 112 for the interrupter roller contact 32, as best shown in Fig. 2. The contact path 112 is provided therein with circumferentially spaced recesses

114 and 116 respectively corresponding to the open and closed positions 34 and 36 of the interrupter switch 26, the recess 116 being formed in the closed-position contact 36. The interrupter roller contact 32, as best shown in Fig. 3 of the drawings, is movable between the recesses 114 and 116 and is rotatably mounted on toggle arms 118 pivoted on a contact carrier 120. The toggle arms 118 are acted on by a resilient means, having the form of a tension spring 122, which biases the roller contact 32 into engagement with the contact path 112 and which tends to hold the roller contact in either the recess 114 or the recess 116.

The interrupter switch 26 includes a rotary actuating means or actuator 124 which is rotatably mounted on a shaft 126, the latter, in turn, being rotatably carried by the mounting plate 82 and a bearing plate 128 on the studs 72. Between the rotary actuator 124 and the contact carrier 120 is a rockable lost-motion connection which forms part of the resilient lost-motion connection 48 hereinbefore mentioned. The manner in which the contact carrier 120 is rockably connected to the rotary actuator 124 will be apparent from a comparison of Figs. 2 and 3 of the drawings and is fully described in my Patent No. 2,831,073. The angular lost motion between the rotary actuator 124 and the contact carrier 120 is limited by kicking means or kickers 130 on the rotary actuator which are engageable with the contact carrier, one of these kickers being operative in response to rotation of the actuator 124 relative to the contact carrier in one direction and the other kicker being responsive to rotation of the actuator in the opposite direction. As will be apparent from Fig. 3 of the drawings, the interrupter roller contact 32 remains in the recess 114 or 116 in which it is disposed until sufficient relative rocking of the contact carrier 120 and the rotary actuator 124 to bring one of the kickers 130 into engagement with the contact carrier has occurred. When the end of the range of lost motion provided by the lost-motion connection 48 has thus been reached, the interrupter roller contact 32 is forced out of the recess 114 or 116 in which it is disposed, the roller contact being caused to jump to the next recess by resiliently stored energy in a manner to be described.

Considering the bidirectional coupling means 46 between the rotary solenoid 20 and the interrupter switch 26, the long arm 98 of the yoke 94 on the armature shaft 92 is received between two arms 132, Figs. 1, 7 and 8, of an interrupter block 134 which is rotatably mounted on the shaft 126. (One of the interrupter-block arms 132 engages an arm of a torsion spring 136, Fig. 7, which is coiled around a pin 138 on the mounting head 70 and the other arm of which is seated against the mounting head. When the rotary solenoid 20 is energized, the yoke 94 is advanced so that the long arm 98 thereof acts on one of the interrupter-block arms 132 to advance the interrupter block 134, thereby stressing the torsion spring 136. Upon subsequent deenergization of the rotary solenoid 20, the torsion spring 136 assists the previously-described spiral return spring 100 in returning the armature 22 of the rotary solenoid 20 to its initial position.) The interrupter block 134 is provided therein with a notch 140, Figs. 1, 2, 3 and 8, which receives and is wider than an arm 142 connected to the rotary actuator 124 of the interrupter switch 26. A generally U-shaped spring 144 is secured to the interrupter block 134 at its mid-point, as by a screw 146, Fig. 8 and the ends of this spring register with the notch 140 in the interrupter block and engage opposite sides of the arm 142.

As will be apparent, when the armature 22 of the rotary solenoid 20 is moved in one direction by energization of the solenoid coil 24, or when the armature is moved in the opposite direction by the return springs 100 and 136, the long arm 98 of the yoke 94 rotates the interrupter block 134 relative to the arm 142 of the rotary actuator 124 to stress the spring 144, due to the lost motion between the interrupter block and the rotary actuator provided by making the notch 140 wider than the arm 142. Thus, energy is stored in the spring 144 and, when one or the other of the kickers 130 has disengaged the interrupter roller contact 32 from one or the other of the recesses 114 and 116, such stored energy causes the interrupter roller contact to jump to the next recess independently of the rotary solenoid 20. Thus, the spring 144 and the lost motion associated therewith form parts of the resilient lost-motion connection 48 of the bidirectional coupling means 46 between the rotary solenoid 20 and the interrupter switch 26, it being apparent that the coupling means 46 operates identically in both directions of movement of the rotary-solenoid armature 22.

It should be noted that the tension spring 122 acting on the toggle arms 118 which carry the interrupter roller contact 32 also stores energy, as the roller contact 32 is kicked out of one or the other of the recesses 114 and 116, which cooperates with the energy stored in the spring 144 to cause the roller contact to jump to the next recess. In other words, after the contact carrier 120 has been rocked into the position relative to the rotary actuator 124 which is shown in Fig. 3 of the drawings and has been displaced from one or the other of the recesses 114 and 116, the tension spring 122 contracts to rock the contact carrier back into its initial position relative to the rotary actuator and thus to propel the interrupter roller contact 32 along the contact path 112 toward and into the next recess. The stored-energy jump of the interrupter roller contact 32 occurs very rapidly to minimize arcing and occurs independently of further movement of the rotary-solenoid armature 22 occurring after the roller contact has left the recess 114 or 116 in which it was initially disposed.

Turning now to a consideration of the structure of the control switch 28, it includes a stator 150 providing an arcuate contact path 152 having therein circumferentially spaced recesses 154 formed in the stationary control contacts 40, as best shown in Figs. 4, 10 and 11 of the drawings. Since the control switch 28 is driven unidirectionally in a manner to be described, the configurations of the recesses 154 preferably differ from the configurations of the recesses 114 and 116 associated with the bidirectionally driven interrupter switch 26. In the case of the interrupter switch, both sides of each of the recesses 114 and 116 are constituted by arcuate, generally radial shoulders conforming to the configuration of the interrupter roller contact 32, thereby providing positive stops for the interrupter roller contact in both directions of travel thereof. However, since the control switch 28 is unidirectionally driven, only the trailing sides of the recesses 154 need be arcuate, generally radial shoulders conforming in curvature to the control roller contact 38 to act as stops therefor, the trailing sides of the recesses 154 being identified by the numeral 156 in Figs. 10 and 11 of the drawings. The other or leading side of each recess 154 is identified by the numeral 158 in Figs. 10 and 11 and extends smoothly substantially from the trailing side 156 of the preceding recess to the bottom of the recess which it cooperates in forming. Thus, as the control roller contact 38, which moves in the direction of the arrows 160 in Figs. 10 and 11 of the drawings, disengages the trailing side 156 of one of the recesses 154, it has, in effect, a downhill run all the way to the bottom of the next recess 154 and into engagement with the stop provided by the trailing side 156 thereof, this downhill run being due to the fact that the leading side 158 of each recess 154 is at an increasing distance from the center of the contact path 152 in the direction of movement of the control roller contact 38. This construction of the recesses 154 helps to insure that the control roller con-

tact 38 will move all the way to the bottom of the next recess after it leaves the preceding recess, which is an important feature of the invention.

Continuing to consider the control switch 28, the control roller contact 38 is mounted on a contact carrier 162, Figs. 1 and 4, in exactly the same manner as the interrupter roller contact 32 is mounted on the contact carrier 120, the control roller contact 38 being spring biased relative to the contact carrier 162 by a spring 163, Fig. 1, in exactly the same manner as the interrupter roller contact 32 is spring biased relative to the contact carrier 120 by the tension spring 122. Consequently, a detailed description is not necessary.

The contact carrier 162 is driven by a rotary actuating means or actuator 164 which is connected at one end to a plate 165 secured to the shaft 126 and which is rotatably connected at its other end to the end plate 88, the rotatable connection between the rotary actuator 164 and the end plate 88 being indicated by the numeral 166 in the Fig. 1 of the drawings. There is a rockable lost-motion connection between the rotary actuator 164 and the contact carrier 162 which is identical to the rockable lost-motion connection between the rotary actuator 124 and the contact carrier 120 so that a detailed description is unnecessary. This lost-motion connection between the rotary actuator 164 and the contact carrier 162 is rendered resilient, to form the resilient lost-motion connection 54, by the spring 163 incorporated in the contact carrier 162 and acting on the control roller contact 38 in the same manner as the tension spring 122 is carried by the contact carrier 120 and acts on the interrupter roller contact 32. The rotary actuator 164 is provided with a kicker 168 engageable with the contact carrier 162 to force the control roller contact 38 out of engagement with the trailing sides 156 of the recesses 154 in the same manner as the interrupter roller contact 32 is kicked out of one or the other of the recesses 114 and 116. After the kicker 168 displaces the control roller contact 38 out of one of the recesses 154, the energy stored in the spring 163 in the contact carrier 162 causes the control roller contact 38 to jump to the next recess in the same manner as the spring 122 causes the interrupter roller contact 32 to jump from one recess 114 or 116 to the next. Again, the stored-energy jump of the control roller contact 38 is independent of the motion of the rotary solenoid 20.

The programming switches 30 are identical to the control switch 28 and all of the components of the programming switches are axially aligned with the corresponding components of the control switch. Consequently, an extremely detailed description of the programming switches 30 will be unnecessary. Briefly, each programming switch 30 includes a stator 170, Fig. 1, which provides a contact path 172 having therein circumferentially spaced recesses 174 identical to the recesses 154 and formed in the stationary programming contacts 44, respectively. Each programming switch 30 includes a contact carrier 176 for the corresponding programming roller contact 44 which is identical to the contact carrier 120, the two contact carriers 176 and the contact carrier 162 being integral to move the control roller contact 38 and the programming roller contacts 42 in unison. The contact carriers 176 are driven by rotary actuators 178 which are integral with the rotary actuator 164 and which have the same relationship to the contact carriers 176 as the rotary actuator 124 has to the contact carrier 120, including identical resilient, rockable lost-motion connections and kicking relationships. Thus, the programming switches 30 operate in exactly the same manner as the control switch 28 and operate in unison therewith.

Digressing for the time being, and referring to Figs. 10 and 11 of the drawings, the insulating segments of the contact path 152 of the control switch 28 are provided therein with gaps 180 adjacent the trailing sides 156 of the recesses 154, respectively. These gaps are narrow as compared to the recesses 154 and as compared to the diameter of the control roller contact 38. Such narrowness of the gaps 180, coupled with their locations adjacent the trailing sides of the recesses 154, insures that the control roller contact 38 will not drop into such gaps as it passes thereover due to the fact that the sored-energy jump of the control roller contact is substantially at its peak, i.e., the stored energy driving the control roller contact is substantially at its peak value when the control roller contact passes over one of the gaps 180. The purpose of the gaps 180 is to prevent metal tracking by the control roller contact 38 over the insulating segments of the contact path 152 between the stationary contacts 40 thereon, which is an important feature of the invention. The contact paths 172 of the programming switches 30 are provided with similar gaps, not shown, for the same purpose.

Considering now the unidirectional coupling means 50 and 52 respectively connecting the control and programming switches 28 and 30 to the rotary solenoid 20, the resilient lost-motion connections 54 and 56 of the respective unidirectional coupling means 50 and 52 have already been described. The remaining components of the unidirectional coupling means are common to all of these coupling means.

Considering the components common to the unidirectional coupling means 50 and 52, the arms 96 and 98 of the yoke 94 extend into openings 190 in a plate 192 having therein notches 194 for tabs 196 on a ratchet disc 198. The openings 190 are spaced 180° apart and the notches 194 are similarly spaced 180° apart, but spaced 90° from the openings 190. The ratchet disc 198 is engageable with a complementary ratchet disc 200 fixed on the shaft 126, the ratchet disc 198 being biased into engagement with the ratchet disc 200 by a leaf spring 202. When the rotary solenoid 20 is energized, the ratchet disc 198 drives the ratchet disc 200 to rotate the shaft 126, the ratchet disc 198 being driven by the yoke 94 through the plate 192. However, during the return stroke of the rotary solenoid 20, which stroke is produced by the return springs 100 and 136, the ratchet disc 198 slips relative to the ratchet disc 200 so that the shaft 126 remains stationary. The shaft 126 and the integral rotary actuators 164 and 178 of the control and programming switches 28 and 30 are nonrotatably interconnected through the plate 165, as illustrated in Fig. 9 of the drawings.

Thus, the foregoing common elements of the unidirectional coupling means 50 and 52 respectively connecting the control and programming switches 28 and 30 to the rotary solenoid 20 cause the control roller contact 38 and the programming roller contacts 42 to advance in the manner hereinbefore discussed only during the advance stroke of the rotary solenoid, the control roller contact and the programming roller contacts remaining in the recesses 154 and 174 in which they are disposed during the return stroke of the rotary solenoid. However, as previously pointed out, the bidirectional coupling means 46 between the interrupter switch 26 and the rotary solenoid 20 causes the interrupter roller contact 32 to move bidirectionally with the rotary solenoid.

Considering the operation of the programmer, it will be apparent that the resilient, energy-storing, lost-motion connection 48 between the rotary solenoid 20 and the interrupter switch 26 causes the interrupter roller contact 32 to lag the rotary-solenoid armature 22 in both directions of movement of the armature, this lag approaching the stroke of the rotary solenoid so that the armature is approaching its advanced position when the interrupter roller contact 32 leaves its closed-position recess 116 and so that the armature is approaching its initial position when the interrupter roller contact leaves its open-position recess 114. This mechanically-introduced lag in the operation of the interrupter roller contact 32 is

an extremely important feature of the invention for two reasons. First, during the advance stroke of the rotary solenoid **20**, the interrupter roller contact **32** remains in its closed-position recess **116** until the armature **22** has approached the end of its advance stroke so that the rotary solenoid is not deenergized by movement of the interrupter roller contact out of its closed-position recess until the armature is nearly at the end of its advance stroke. Consequently, the decaying field in the coil **24** and the inertia of the armature **22** will insure movement of the armature to the end of its advance stroke, the few degrees that the armature coasts providing a cushion to minimize shock. Second, the mechanically-introduced lag of the interrupter roller contact **32** insures that the armature **22** will be almost at the end of its return stroke before the interrupter roller contact leaves its open-position recess **114**, the return springs **100** and **136** thus returning the armature to its initial position prior to the instant, or not later than the instant, at which the interrupter roller contact enters the closed-position recess **116** to reenergize the rotary solenoid, assuming here that the rotary solenoid is in series with a closed regulating switch **60** at such instant. The lag of the interrupter roller contact **32** thus prevents premature reenergization of the rotary solenoid **20**. Thus, the operative relationship between the rotary solenoid **20** and the interrupter switch **26** is positive and reliable in both directions due to the lag introduced by the resilient lost-motion connection **48** of the bidirectional coupling means **46**, which is an important feature of the invention.

The resilient lost-motion connections **48**, **54** and **56** between the rotary solenoid **20** and the interrupter, control and programming switches **26**, **28** and **30** cause the roller-contact movements to be independent of the rotary solenoid once the roller contacts have broken out of the recesses in which they are disposed. The stored-energy jumps of the interrupter, control and programming switches **26**, **28** and **30** occur so rapidly that the roller contacts outrace the rotary solenoid so that the rotary solenoid has no influence on the movements of the roller contacts once they have broken out of their recesses. This action, coupled with the fact that the roller contacts **32**, **38**, and **42** are positively detented into the recesses into which they jump by their biasing springs, insures that the roller contacts will always reach the recesses into which they are intended to go, and that they will drop safely thereinto and be held therein positively. Consequently, the over-all effect is a positive and reliable roller-contact movement without any possibility of skipping.

It should be pointed out in connection with the foregoing that the downhill runs which the control and programming roller contacts **38** and **42** make into their recesses further insure that these roller contacts will enter the intended recesses, there being no possibility that these roller contacts will stop short of the desired recesses.

It is important that the interrupter and control roller contacts **32** and **38** break out of their recesses at the same instant to insure uniform and dependable energization of the rotary solenoid **20**. To achieve this, the degrees or amounts of lost motion in the connections between the rotary solenoid **20** and the interrupter and control switches **26** and **28** are made equal.

It is also important that the control and programming roller contacts **38** and **42** break out of their recesses simultaneously and enter the succeeding recesses simultaneously to be assured of simultaneous program controls, this being accomplished by interconnecting the control contact carrier **162** and the programming contact carriers **176** as hereinbefore described.

Since the roller contacts **32**, **38** and **42** are transferred from recess to recess by the energy stored in the lost-motion connections **48**, **54** and **56** associated therewith, and are thus transferred independently of the rotary solenoid **20** once they break out of their recesses, the angular stroke of the rotary solenoid may be less than the circumferential spacings of the recesses in the interrupter, control and programming contact paths **112**, **152** and **172**. Such a reduced angular stroke for the rotary solenoid **20** permits the use of a rotary solenoid having reduced weight and current requirements. Also, the circumferential spacing of the recesses in the control and programming contact paths **152** and **172** may exceed that of the recesses in the interrupter contact path **112** in view of the downhill runs of the control and programming roller contacts **38** and **42** into their recesses **154** and **174**.

The over-all operation of the programmer of the invention, and particularly the relationship between the movements of the rotary-solenoid armature **22**, the interrupter roller contact **32** and the control and programming roller contacts **38** and **42**, may best be understood with reference to Figs. 13*a* to 13*f*, which show the relative positions of these elements at various instants in the operating cycle of the programmer. Referring to Fig. 13*a*, it will be assumed that the armature **22** and the roller contacts **32**, **38** and **42** are all at rest, the at-rest positions of these elements being designated as 0° positions in Fig. 13*a*. Under such conditions, the armature **22** is in its initial or starting position and the roller contacts **32**, **38** and **42** are all centered relative to the ranges of lost motion provided by the corresponding resilient lost-motion connections **48**, **54** and **56**. Such equilibrium conditions may be insured upon assembly of the programmer of the invention by relatively rotating the rotary solenoid **20**, the interrupter switch **26** and the control and programming switches **28** and **30** until the proper relative angular positions are achieved, this being permitted by the hereinbefore-described circumferentially extending slots in the mounting plates **78** and **82** through which the screws **76** and the studs **80** extend.

Turning to Fig. 13*b*, the armature **22** is shown as rotating through an angle of 5°, as indicated by the arrow **201**, as the result of energization of the coil **24** through the interrupter switch **26** and the control switch **28**. Such angular advance of the armature **22** is sufficient to take up the lost motion provided by the angular clearance between the interrupter block **134** and the rotary actuator **124** and the lost motion between the ratchet discs **198** and **200**. Consequently, the roller contacts **32**, **38** and **42** are still in their 0° positions at this stage.

Considering Fig. 13*c*, the armature **22** is shown as rotating through a 26° position, as indicated by the arrow **203**, the armature now being within 9° of the end of its 35° advance stroke shown in Fig. 13*d*. With the armature **22** advanced 26°, the roller contacts **32**, **38** and **42** have been rotated through angles of 5° and are breaking out of their respective recesses, as indicated by the arrows **204** and **206** associated with the two 5° vectors. At this point, the rotary solenoid **20** is still energized, but it will be deenergized a split second later as the roller contact **32** jumps away from the closed-position stationary contact **36**.

Even though the rotary solenoid **20** is deenergized during the interval between Figs. 13*c* and 13*d*, the decaying field in the coil **24** and inertia carry the armature **22** on to the end of its advance stroke, as indicated by the 35° position in Fig. 13*d*. At about the instant the armature **22** reaches its advanced position, or shortly thereafter, the roller contact **32** reaches a 39° position and drops into the open-position recess **114** and the roller contacts **38** and **42** reach 45° positions and drop into certain of the recesses **154** and **174**, respectively. The arrows **208** and **210** indicate that the contact **32** does not reach its 39° position and that the contacts **38** and **42** do not reach their 45° positions prior to the time that the armature **22** reaches its 35° position.

Turning now to Fig. 13*e* of the drawings, the return springs **100** and **136** are moving the armature **22** through a position within 9° of its initial position, as indicated by the arrow **211**. At this point, the interrupter roller contact **32** has been moved back to its 34° position and is

breaking out of its open-position recess **114**, as indicated by the arrow **212**. The control and programming roller contacts **38** and **42**, of course, remain in their 45° positions.

Considering Fig. 13*f*, the armature **22** has returned to its initial or 0° position, and the interrupter roller contact **32** is returning to its 0° position and is dropping into the closed-position recess **116**, as indicated by the arrow **214**. As previously stated, the armature **22** returns to its initial position no later than the instant that the interrupter roller contact **32** returns to the closed-position recess **116** so as to prevent premature reenergization of the solenoid **20**.

If, at this stage, the control roller contact **38** is connected to an open control circuit **58**, the solenoid **20** will not be reenergized. However, if the control roller contact **38** encounters a closed control circuit **58**, or if the open control circuit **58** which it engages is thereafter closed, the solenoid **20** will be reenergized and the foregoing cycle of events will be repeated.

It will be understood that the exact numerical values given in Figs. 13*a* to 13*f* are intended as illustrative only, there being no intention of limiting the invention specifically thereto.

Although an exemplary embodiment of the invention has been disclosed herein for purposes of illustration, it will be understood that various changes, modifications and substitutions may be incorporated in such embodiment without departing from the spirit of the invention as defined by the claims which follow.

I claim as my invention:

1. In combination: control circuits respectively including stationary control contacts and regulating switches in series, said stationary control contacts being arranged in circumferentially spaced relation; a rotatable control contact electrically engageable with said stationary control contacts seriatim; an oscillatory drive means; electrically energizable means for moving said drive means in one direction; means for moving said drive means in the opposite direction; unidirectional coupling means mechanically coupling said rotatable control contact to said drive means for engaging said rotatable control contact with said stationary control contacts seriatim in response to successive energizations of said electrically energizable means; an oscillatory interrupter contact movable between open and closed positions and electrically connected in series with said electrically energizable means and said rotatable control contact when said interrupter contact is in said closed position, whereby said electrically energizable means is energizable when said interrupter contact is in said closed position and when said rotatable control contact is engaged with any of said stationary control contacts the regulating switches in series with which are closed; and bidirectional coupling means mechanically coupling said interrupter contact to said drive means so as to oscillate said interrupter contact between said open and closed positions as said drive means is oscillated.

2. In combination: control circuits respectively including stationary control contacts and regulating switches in series, said stationary control contacts being arranged in circumferentially spaced relation; a rotatable control contact electrically engageable with said stationary control contacts seriatim; an oscillatory drive means; electrically energizable means for moving said drive means in one direction; means for moving said drive means in the opposite direction; unidirectional coupling means mechanically coupling said rotatable control contact to said drive means for engaging said rotatable control contact with said stationary control contacts seriatim in response to successive energizations of said electrically energizable means; an oscillatory interrupter contact movable between open and closed positions and electrically connected in series with said electrically energizable means and said rotatable control contact when said interrupter contact is in said closed position, whereby said electrically energizable means is energizable when said interrupter contact is in said closed position and when said rotatable control contact is engaged with any of said stationary control contacts the regulating switches in series with which are closed; and bidirectional coupling means mechanically coupling said interrupter contact to said drive means so as to oscillate said interrupter contact between said open and closed positions as said drive means is oscillated, said bidirectional coupling means including a lost-motion mechanical connection between said interrupter contact and said drive means to cause said interrupter contact to lag said drive means as the latter is moved in either direction.

3. In combination: control circuits respectively including stationary control contacts and regulating switches in series, said stationary control contacts being arranged in circumferentially spaced relation; a rotatable control contact electrically engageable with said stationary control contacts seriatim; an oscillatory drive means; electrically energizable means for moving said drive means in one direction; means for moving said drive means in the opposite direction; unidirectional coupling means mechanically coupling said rotatable control contact to said drive means for engaging said rotatable control contact with said stationary control contacts seriatim in response to successive energizations of said electrically energizable means, said unidirectional coupling means including a first resilient lost-motion mechanical connection between said rotatable control contact and said drive means for causing said rotatable control contact to lag said drive means; an oscillatory interrupter contact movable between open and closed positions and eletrically connected in series with said electrically energizable means and said rotatable control contact when said interrupter contact is in said control position, whereby said electrically energizable means is energizable when said interrupter contact is in said closed position and when said rotatable control contact is engaged with any of said stationary control contacts the regulating switches in series with which are closed; and bidirectional coupling means mechanically coupling said interrupter contact to said drive means so as to oscillate said interrupter contact between said open and closed positions as said drive means is oscillated, said bidirectional coupling means including a second resilient lost-motion mechanical connection between said interrupter contact and said drive means for causing said interrupter contact to lag said drive means in both directions of movement of said drive means, said second lost-motion connection having the same degree of lost motion as said first lost-motion connection.

4. In combination: control circuits respectively including stationary control contacts and regulating switches in series, said stationary control contacts being arranged in circumferentially spaced relation; a rotatable control contact electrically engageable with said stationary control contacts seriatim; an oscillatory driven means; electrically energizable means for moving said drive means in one direction; means for moving said drive means in the opposite direction; unidirectional coupling means mechanically coupling said rotatable control contact to said drive means for engaging said rotatable control contact with said stationary control contacts seriatim in response to successive energizations of said electrically energizable means; an oscillatory interrupter contact movable between open and closed positions and electrically connected in series with said electrically energizable means and said rotatable control contact when said interrupter contact is in said closed position, whereby said electrically energizable means is energizable when said interrupter contact is in said closed position and when said rotatable control contact is engaged with any of said stationary control contacts the regulating switches in series with which are closed; bidirectional coupling means mechanically coupling said interrupter contact to said drive means so as to oscillate said interrupter contact

between said open and closed positions as said drive means is oscillated, said bidirectional coupling means including a resilient lost-motion mechanical connection between said interrupter contact and said drive means to cause said interrupter contact to lag said drive means as the latter is moved in either direction; programming means including stationary programming contacts arranged in circumferentially spaced relation and a rotatable programming contact engageable with said stationary programming contacts seriatim; and another unidirectional coupling means mechanically coupling said rotatable programming contact to said drive means for connecting said rotatable programming contact to said stationary programming contacts seriatim in response to successive energizations of said electrically energizable means.

5. In combination: control circuits respectively including stationary control contacts and regulating switches in series, said stationary control contacts being arranged in circumferentially spaced relation; a rotatable control contact electrically engageable with said stationary control contacts seriatim; an oscillatory drive means; electrically energizable means for moving said drive means in one direction; means for moving said drive means in the opposite direction; unidirectional coupling means mechanically coupling said rotatable control contact to said drive means for engaging said rotatable control contact with said stationary control contacts seriatim in response to successive energizations of said electrically energizable means, said unidirectional coupling means including a first resilient lost-motion mechanical connection between said rotatable control contact and said drive means for causing said rotatable control contact to lag said drive means; an oscillatory interrupter contact movable between open and closed positions and electrically connected in series with said electrically energizable means and said rotatable control contact when said interrupter contact is in said closed position, whereby said electrically energizable means is energizable when said interrupter contact is in said closed position and when said rotatable control contact is engaged with any of said stationary control contacts the regulating switches in series with which are closed; bidirectional coupling means mechanically coupling said interrupter contact to said drive means so as to oscillate said interrupter contact between said open and closed positions as said drive means is oscillated, said bidirectional coupling means including a second resilient lost-motion mechanical connection between said interrupter contact and said drive means for causing said interrupter contact to lag said drive means in both directions of movement of said drive means, said second lost-motion connection having the same degree of lost motion as said first lost-motion connection; programming means including stationary programming contacts arranged in circumferentially spaced relation and a rotatable programming contact engageable with said stationary programming contacts seriatim; and another unidirectional coupling means mechanically coupling said rotatable programming contact to said drive means for connecting said rotatable programming contact to said stationary programming contacts seriatim in response to successive energizations of said electrically energizable means, said other unidirectional coupling means including a third resilient lost-motion mechanical connection between said rotatable programming contact and said drive means for causing said rotatable programming contact to lag said drive means, said third lost-motion connection having a degree of lost motion equal to the degrees of lost motion of said first and second lost-motion connections.

6. In combination: control circuits; switch means electrically connectible in series with said control circuits seriatim; electrically energizable means connected in series with said switch means for electrically connecting said switch means in series with said control circuits seriatim; and interrupter means in series with said switch means and said electrically energizable means and actuable by said electrically energizable means for alternately permitting and preventing energization of said electrically energizable means, whereby said electrically energizable means is energizable when said interrupter means permits energization thereof and when said switch means is electrically connected in series with any of said control circuits which are closed.

7. In combination: a rotary solenoid; a rotary interrupter switch coaxial with and electrically connected in series with said rotary solenoid; coupling means coupling said interrupter switch to said rotary solenoid for movement therewith, said coupling means including a resilient lost-motion connection; a rotary, multi-position control switch coaxial with and electrically connected in series with said interrupter switch and said rotary solenoid, whereby said rotary solenoid is energizable only when said interrupter switch is closed and said control switch is in a closed position; and another, unidirectional coupling means coupling said control switch to said rotary solenoid to be driven thereby, said other coupling means including a resilient lost-motion connection.

8. In combination: a rotary solenoid; a rotary interrupter switch coaxial with and electrically connected in series with said rotary solenoid; coupling means coupling said interrupter switch to said rotary solenoid for movement therewith, said coupling means including a resilient lost-motion connection; a rotary, multi-position control switch coaxial with and electrically connected in series with said interrupter switch and said rotary solenoid, whereby said rotary solenoid is energizable only when said interrupter switch is closed and said control switch is in a closed position; another, unidirectional coupling means coupling said control switch to said rotary solenoid to be driven thereby said other coupling means including a resilient lost-motion connection; a rotary, multi-position programming switch coaxial with said rotary solenoid, said interrupter switch and said control switch; and a third, unidirectional coupling means coupling said programming switch to said rotary solenoid to be driven thereby, said third coupling means also including a resilent lost-motion connection.

9. The combination set forth in claim 8 wherein the second and third lost-motion connections recited have substantially the same degrees of lost motion as the first lost-motion connection defined.

10. In combination: a rotary solenoid; rotary interrupter, control and programming switches axially aligned with said rotary solenoid; bidirectional coupling means coupling said rotary solenoid to said interrupter switch; unidirectional coupling means coupling said control switch and said programming switch to said rotary solenoid; and electrical circuit means interconnecting said rotary solenoid, said interrupter switch and said control switch in series.

11. The combination set forth in claim 10 wherein said rotary switches respectively include circumferentially spaced stationary contacts successively engageable by rotatable contacts, said coupling means including resilient lost-motion connections between said rotary solenoid and said rotatable contacts, said lost-motion connections having substantially the same amounts of lost motion.

12. In combination: an arcuate, concave contact path having a center of curvature and having circumferentially spaced, radially inwardly directed, recesses therein and having thereon at least one stationary contact in which one of said recesses is formed; a contact carrier located radially inwardly of and movable adjacent and parallel to said contact path; a roller contact carried by said contact carrier and movable along said contact path and receivable in each of said recesses; actuating means movable about said center of curvature of said contact path for moving said contact carrier adjacent and parallel to said contact path; means providing a resilient lost-motion

connection between said actuating means and said contact carrier; kicking means carried by said actuating means and engageable with said contact carrier for limiting the range of lost motion between said actuating means and said contact carrier so as to kick said roller contact out of each of said recesses; resilient means for biasing said roller contact into engagement with said contact path; a rotary solenoid coaxial with said contact path; and coupling means interconnecting said rotary solenoid and said actuating means so that energization of said rotary solenoid results in movement of said roller contact from one of said recesses in said contact path to the next.

13. In combination: a rotary solenoid having a predetermined angular stroke; a rotary switch aligned with said rotary solenoid and including an arcuate contact path having circumferentially spaced recesses therein and including a roller contact engaging and movable along said contact path and receivable in each of said recesses, the angular spacing of said recesses exceeding said angular stroke of said rotary solenoid; and coupling means mechanically coupling said roller contact to said rotary solenoid and including a resilient lost-motion mechanical connection capable of storing energy, whereupon energy stored in said lost-motion connection produces movement of said roller contact from one of said recesses to the next upon sufficient rotary movement of said rotary solenoid relative to said roller contact to take up the lost motion provided by said lost-motion connection and thus force said roller contact out of said one recess.

14. In combination: an arcuate contact path having circumferentially spaced recesses therein, one side of each recess being defined by an arcuate shoulder and the other side of such recess being defined by a surface which extends from the bottom of such recess substantially to the shoulder of the adjacent recess; and a roller contact movable along said contact path in a direction such that said roller contact moves from said shoulder of each recess along said surface of and toward and into engagement with said shoulder of the succeeding recess.

15. In combination: an arcuate contact path having circumferentially spaced recesses therein, each of said recesses having leading and trailing sides, said contact path having gaps therein adjacent the trailing sides of said recesses, respectively, which are narrow as compared to said recesses; and a roller contact movable along said contact path into and out of said recesses and over said gaps in a direction from the leading side of each of said recesses toward the trailing side thereof.

16. In combination: control circuits respectively including stationary control contacts and regulating switches in series, said stationary control contacts being spaced apart along a control contact path; a movable control contact movable along said control contact path and electrically engageable with said stationary control contacts seriatim; means including an electrically energizable device for moving said movable control contact along said control contact path and into electrical engagement with said stationary control contacts seriatim in a step-by-step manner; and means electrically connecting said electrically energizable device in series with said movable control contact whenever said movable control contact is in electrical engagement with one of said stationary control contacts, whereby said electrically energizable device is energized to move said movable control contact into engagement with an adjacent stationary control contact whenever said movable control contact is in electrical engagement with a stationary control contact the regulating switch in series with which is closed.

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