July 9, 1963 R. E. ALDERMAN 3,097,278

ROTARY SOLENOID ACTUATED SWITCHES

Filed April 13, 1960 3 Sheets-Sheet 1

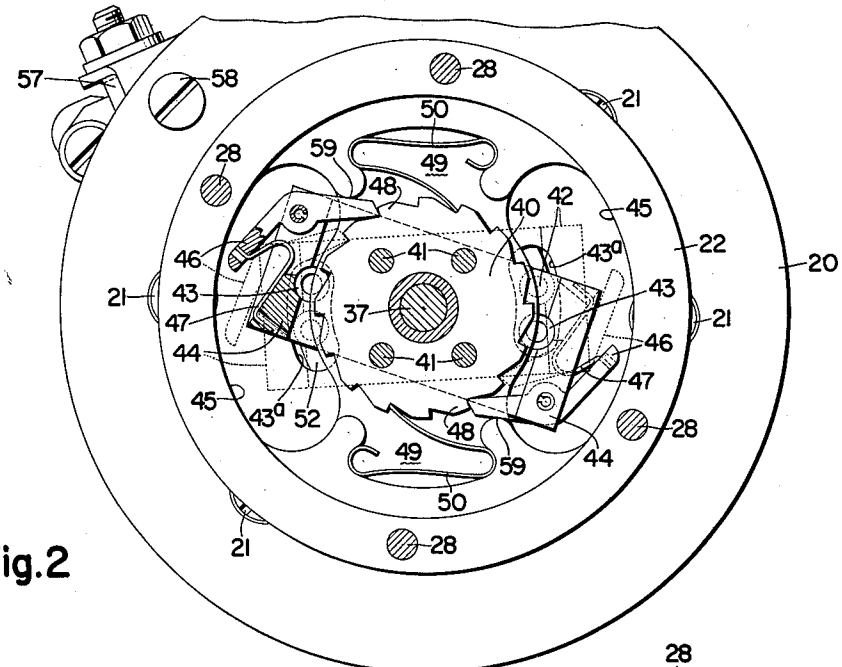


Fig.2

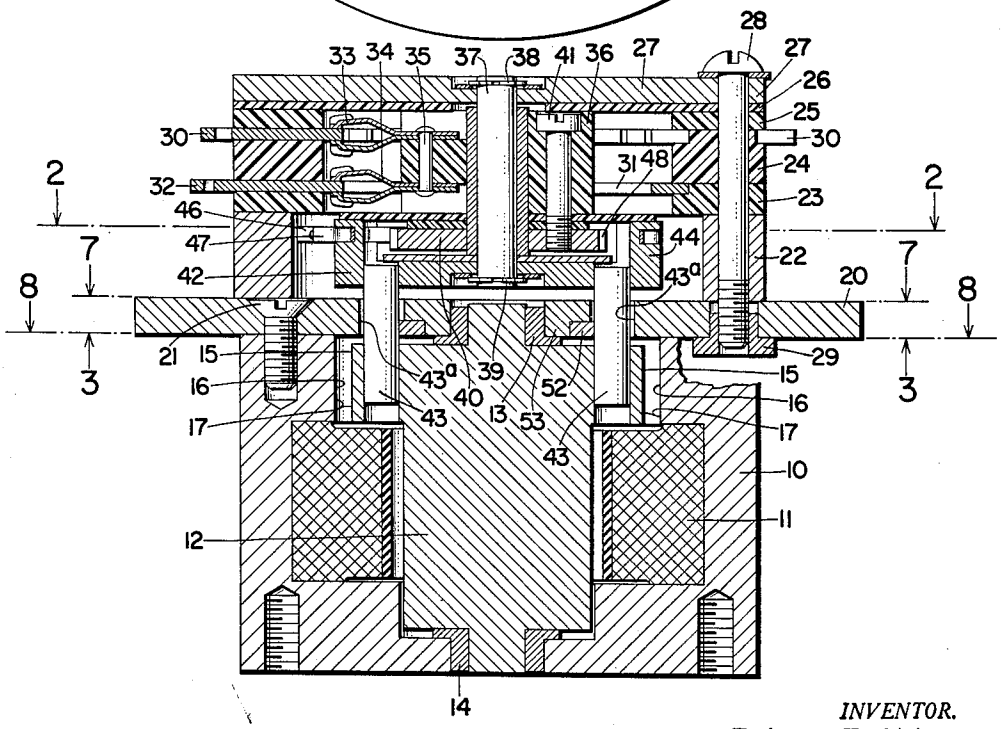


Fig.1

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ROTARY SOLENOID ACTUATED SWITCHES

Filed April 13, 1960 3 Sheets-Sheet 2

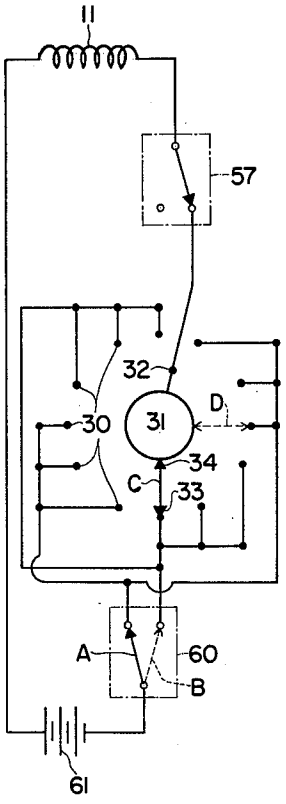


Fig.9

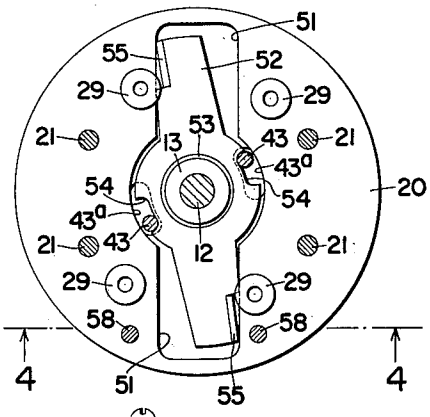


Fig.3

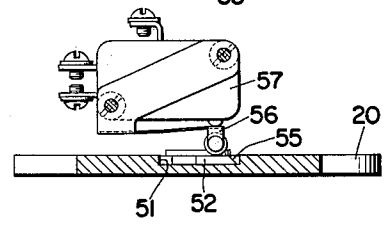


Fig.4

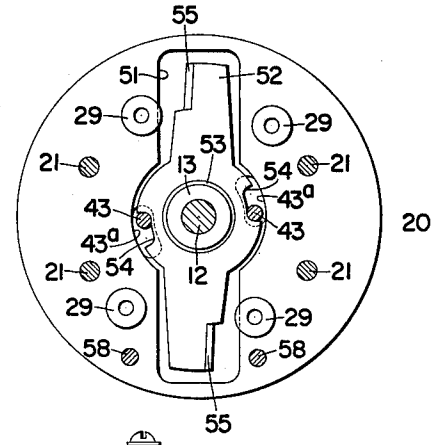


Fig.5

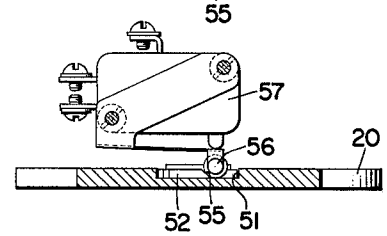


Fig.6

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ROTARY SOLENOID ACTUATED SWITCHES

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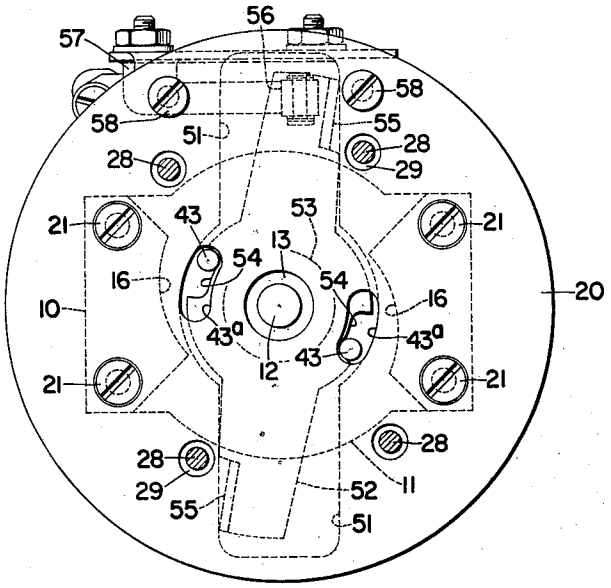


Fig.7

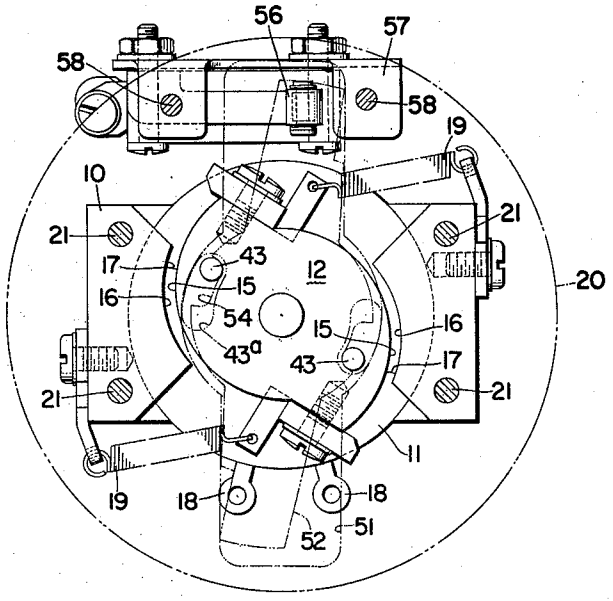


Fig.8

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ROTARY SOLENOID ACTUATED SWITCHES

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5 Claims. (Cl. 200—105)

This invention relates to solenoid actuated switches and more particularly to remotely-controlled stepping switches which are actuated by ratchets driven by rotary solenoids having balanced armatures, including provision for self-cycling.

It is a particular feature of this invention that the switching action is insensitive to adverse environmental accelerations which might otherwise produce false switching.

According to this invention the indexed position of the switch corresponds to a jammed condition of the ratchet to provide positive locking.

A ratchet-driven switch is used in which a yoke with ratchet-engaging members is rotated against spring tension by a rotary solenoid. When the solenoid is deenergized, the stored spring energy is released to rotate the ratchet and index the switch.

For self-cycling action a limit or interrupter switch is used which is actuated by a cam element which is moved by the armature through a lost motion connection to delay the deenergization of the solenoid so that maximum energy is stored in the springs before current is cut off. There is also delay in the reclosing of the limit switch until after the new indexed position of the stepping switch has been established.

The combination of interrupter switch and contacts on the rotary switch permits the rotary switch to step or cycle as many times per voltage application as desired and is of importance in setting up various different sequence switching programs. Banks of contacts can be added to the switch structure in a configuration to suit any required switching problem.

It is an object of this invention to provide a switch which is indexed by the energy stored in a spring by the action of a rotory solenoid.

It is a further object of this invention to provide a switch in which a stable indexed position is created by a jammed condition of the actuator to provide positive locking against the effects of adverse environmental forces.

It is a still further object of this invention to provide a stepping switch having self-cycling action yielding as many steps per voltage application as desired.

With the above and other objects in view, as will hereinafter appear, the invention comprises the devices, combinations and arrangements of parts hereinafter set forth and illustrated in the accompanying drawings of a preferred embodiment of the invention, from which the several features of the invention and the advantages attained thereby, will be readily understood by those skilled in the art.

In the drawings, FIG. 1 is a vertical sectional view taken through the switch embodying the invention.

FIG. 2 is a transverse view, partly in section, taken on line 2—2 of FIG. 1.

FIG. 3 is a transverse view, partly in section, taken on line 3—3 of FIG. 1.

FIG. 4 is a view taken on line 4—4 of FIG. 3.

FIG. 5 is a transverse view, similar to FIG. 3, but with the actuator in different position.

FIG. 6 is a view similar to FIG. 4 but with the actuator in the position indicated in FIG. 5.

FIG. 7 is a transverse view taken on line 7—7 of FIG. 1.

FIG. 8 is a transverse view taken on line 8—8 of FIG. 1.

FIG. 9 is a circuit diagram showing a specific use of the switch of FIG. 1.

Referring now to FIG. 1, 10 indicates a generally U-shaped magnetic core containing an annular winding 11 within which is located an armature 12 journaled for rotation in bearings 13 and 14. The armature 12 is enlarged at one end to form portions 15—15 having substantially involute shapes as shown best in FIG. 8. These involute portions cooperate with opposed polar portions 16—16 of the core 10 to form therebetween a variable air gap 17—17. It will be seen that, when the winding 11 is energized by application of a suitable D.C. voltage to terminals 18—18, the armature 12 is rotated in a direction to decrease the air gap 17—17. That is to say the armature rotates from a position of maximum gap reluctance, in which it is biased by springs 19—19, to a position of minimum gap reluctance in which position the springs 19—19 will be distended further than shown in FIG. 8. This represents energy storage in the springs 19—19 and, when the winding 11 is subsequently deenergized, this energy is released to rotate the armature to its original position. Thus, due to successive energization and deenergization of the winding 11, the armature is given a rotary oscillating movement.

A non-magnetic plate 20 secured to the core 10 by screws 21 serves as a support for the structure now to be described.

A laminated structure, built up of annular spacers 22, 23, 24, 25, 26 and an end disc 27, is secured to the plate 20 by screws 28 threaded into inserts 29. Held between insulated spacers 24 and 25 are a series of radially extending, circumferentially spaced contacts 30. Held between insulated spacers 23 and 24 is an annular conducting ring 31 having a single radial extension 32 for external connection.

Movable switch contacts 33 and 34, secured by a conducting rivet 35 to an insulated hub 36, cooperate with the respective fixed contacts 30 and the conducting ring 31 as shown in FIG. 1. The hub 36 is journaled on a shaft 37 held centrally of the assembly by snap rings 38 and 39. An insulated ratchet wheel 40 is secured for rotation with the hub 36 by screws 41 threaded into the ratchet wheel. It is obvious that, by using additional contacts and spacers with this built-up construction, any number of switching groups may be added to meet special switching program requirements.

Also journaled on the shaft 37 is a yoke 42 drivingly connected to the armature 12 by means of drive pins 43—43 secured to the armature and extending through slots 43*a* in plate 20 as shown in FIG. 1.

As seen best in FIG. 2, the yoke 42 is generally U-shaped with the two limbs 44—44 projecting through cut-out portions 45—45 of the spacer 22. Pawls 46—46 pivoted on the limbs 44—44 are urged by hairpin springs 47—47 into driving engagement with teeth 48 of the ratchet wheel 40. Seated within recesses 49—49 in the spacer 22 are leaf springs 50—50 which engage the teeth 48 of the ratchet wheel 40 to prevent retrograde motion thereof.

As seen best in FIG. 7, the plate 20 is formed with a surface recess 51 within which operates a cam element 52. The cam element 52 is journaled on a shoulder 53 of the plate 20 and is thus constrained to rotate about an axis common to the armature 12. Notches 54—54 formed in the cam element 52 are engaged by the drive pins 43 to provide a lost-motion driving connection between the

armature and the cam element for reasons which will appear later. The cam element **52** is formed at each diametrically opposed end with a ramp portion **55** for the purpose of moving a leaf and roller actuator **56** of an interrupter switch **57** secured to the plate **20** by screws **58—58**.

By reference to FIG. 2, which corresponds to the deenergized condition of the solenoid winding **11**, it will be seen that the pawls **46—46** are held in a wedged or jammed position between abutments **59—59** (formed on the spacer **22**) and teeth **48** of the ratchet wheel **40**. This jammed condition is maintained by action of the springs **19** and corresponds to an indexed position of the switch. That is to say, in this condition of the parts, movable contact **33** is in engagement with one of the fixed contacts **30**.

Operation

When the winding **11** is energized by application of a D.C. voltage to terminals **18—18**, the armature **12** is rotated counterclockwise as viewed in FIG. 8 to reduce the reluctance of the gap **17—17**. This motion stores energy in springs **19—19** as mentioned above and, through the drive pins **43—43**, rotates the yoke **42** to the position shown dotted in FIG. 2, springs **50** preventing any retrograde motion of the ratchet wheel **40** during this action. Upon subsequent deenergization of the winding **11** the stored energy in springs **19—19** is released to rotate the armature **12** back to its original position. This motion is transmitted to the yoke **42** which is rotated clockwise to its position shown in full lines in FIG. 2. By virtue of the engagement of teeth **48** by pawls **46—46**, this return movement of the yoke **42** imparts a similar rotation to the ratchet wheel **40** and thus to the movable switch contact **33** to advance same to the next indexed position. It will be noted that this is a jammed condition as described above. The above situation applied where only one switching step is required per voltage application.

Where self-cycling is desired, the interrupter switch **57** with the cam element **52** are used. The cam element **52** provides means for delaying the opening of switch **57** until the armature has stored sufficient energy in springs **19—19** to insure positive switch indexing. It also provides means for delaying the reclosing of the switch **57** until after the stepping switch has been indexed to its new position. FIGS. 3 and 4 show the positions of cam element **52** and switch **57** in the deenergized condition of winding **11**. The cam element **52** holds the roller actuator **56** to maintain the switch **57** closed. When winding **11** is energized, the armature **12** is rotated and stores energy in springs **19—19** while moving the yoke **42** backward preparatory to the next indexing of the switch. Due to the lost motion provided by the circumferential length of the notches **54—54**, as seen in FIGS. 5 and 6, the armature can rotate through a considerable arc before the pins **43—43** engage the cam element **52** to move it to the position shown to open the switch **57** and deenergize the winding **11**. Upon deenergization of the winding **11**, the springs **19—19** release their stored energy and rotate the armature and, through pins **43—43**, the ratchet **40** and switch **33** to its new indexed position. It will be seen that the same lost-motion connection between pins **43—43** and cam element **52** operates to delay the closing of switch **57** until after the stepping switch **33** has been indexed to its new position.

By way of example, FIG. 9 shows an application of the switch in which three switching steps are completed for each voltage application. An external S.P.D.T. switch **60** is connected to contacts **30** of the stepping switch in alternate groups of three; the circuit being completed through common terminal **32**, interrupter switch **57**, solenoid winding **11** and battery **61**. When switch **60** is thrown from position A to B, the stepping switch **33, 34** moves in three discrete steps from position C to D. When the switch **60** is thrown back to position A, the stepping switch will advance by three more steps, and this action may be repeated as often as switch **60** is operated.

It will be seen that, by using different contact arrangements with this basic switch assembly, any desired switching sequence program may be set up.

It will be perceived that, by the balanced rotary design disclosed above, the switch of this invention is rendered insensitive to any adverse environmental accelerations except for those occurring specifically about the axis of the armature. For the latter, the jamming feature offers protection against false operation. Thus this switch is particularly suited to missile applications where environmental forces cannot be predicted.

Having thus set forth the nature of the invention, what I claim herein is:

1. In a stepping switch, a rotary solenoid, a balanced armature for said solenoid oscillatable between rotary positions of maximum and minimum gap reluctance, spring means for biasing said armature in its position of maximum gap reluctance, a balanced yoke member driven by said armature, pawl elements carried by said yoke member, a ratchet wheel having ratchet teeth and driven by engagement of said pawl elements with said teeth, means cooperating with said ratchet wheel to prevent retrograde rotation thereof, and abutment means cooperating with said pawl elements to provide a stable jammed condition in the biased position of said armature whereby the pawl elements are securely held in wedged position between said abutment means and said ratchet teeth to prevent accidental rotation of the ratchet wheel induced by adverse environmental accelerations.

2. In a rotary stepping switch, a rotary solenoid, a balanced armature for said solenoid oscillatable between rotary positions of maximum and minimum gap reluctance, spring means for biasing said armature in its position of maximum gap reluctance, current-carrying winding means for moving said armature to its position of minimum gap reluctance, movable switch contacts, balanced pawl and ratchet means for imparting unidirectional rotation to said switch contacts from said rotary oscillating motion of said armature, an interrupter switch for controlling the energization of said winding means, and a balanced cam element driven by said armature through a lost-motion connection for actuating said interrupter switch in positions of the armature near each end of its oscillatory movement.

3. In a rotary stepping switch, a rotary solenoid, a balanced armature for said solenoid, means for imparting a rotary oscillating movement to said armature, rotary switch contacts, a ratchet wheel secured for rotation with said switch contacts, a balanced yoke member rotatable about a common axis with respect to said ratchet wheel, pin means secured to said armature and engaged with said yoke to drive same, pivoted pawl means carried by said yoke member and in engagement with said ratchet wheel to impart intermittent unidirectional rotation to said ratch wheel responsively to the rotary oscillating movement of said armature, and stationary abutment means cooperating with said pawl means for establishing a jammed condition of the ratchet wheel in one of the extreme positions of the oscillatory movement of the armature.

4. A rotary stepping switch comprising a balanced rotary armature, a stationary magnetic core forming with said armature a variable air gap, a stationary current-carrying winding having its winding axis common with the axis of rotation of the armature, a rotary contact element, a ratchet wheel secured to said contact element, a balanced yoke element, pawl elements pivoted on said yoke element for one-day driving engagement with said ratchet wheel, and diametrically-positioned pin means secured to the armature and in driving engagement with said yoke member, said rotary contact element, ratchet wheel and yoke member being mounted

for rotation about an axis common to the axis of rotation of said armature.

5. In a self-cycling rotary stepping switch, a rotary contact element, means for imparting to said contact element discrete steps of unidirectional angular movement comprising, a rotary solenoid, a current-carrying winding and a balanced rotary armature for said solenoid, spring means for biasing said armature in one extreme rotary position, means responsive to current in said winding for moving said armature against said spring means to an opposite extreme rotary position, balanced pawl and ratchet means connecting said armature with said contact element, interrupter switch means for controlling the current to said solenoid winding, and balanced cam means driven by said armature through a lost-motion connection for actuating said interrupter switch means in

positions of the armature near to each of its extreme rotary positions.

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