Nov. 3, 1959 H. D. JACKSON 2,910,876

STEPPING DEVICE

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Fig. 1

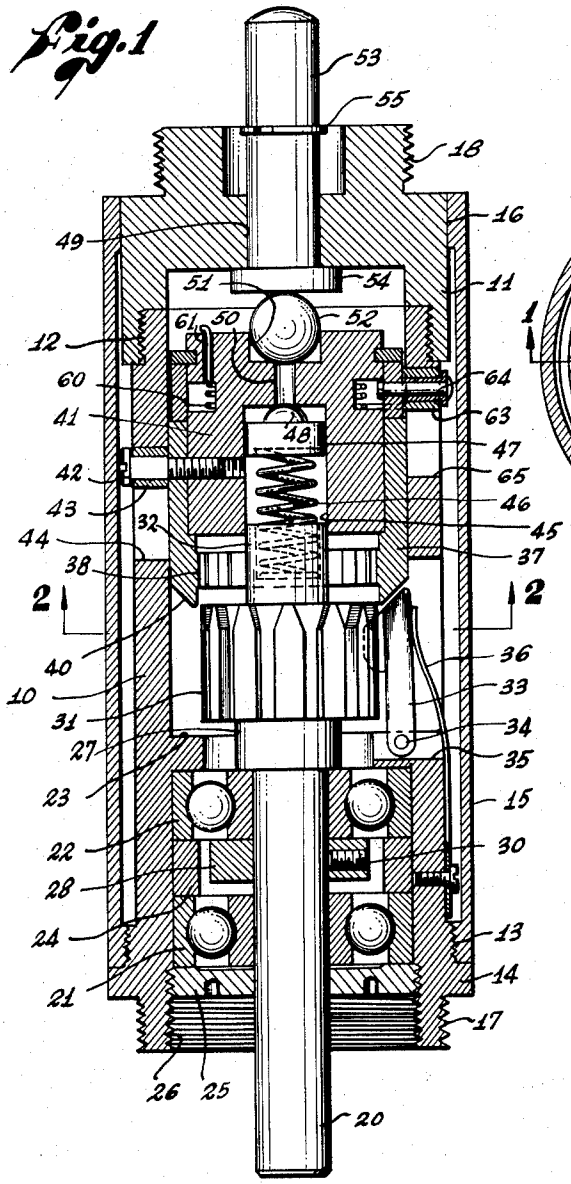


Fig. 2

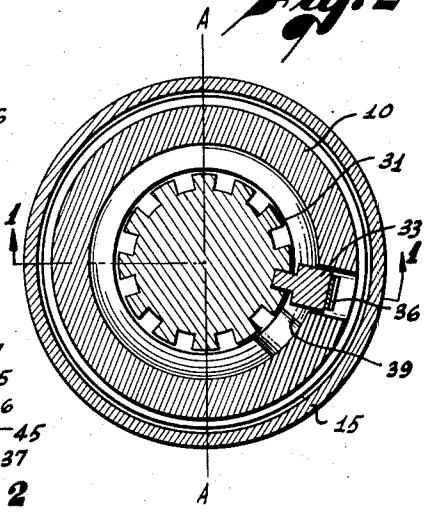
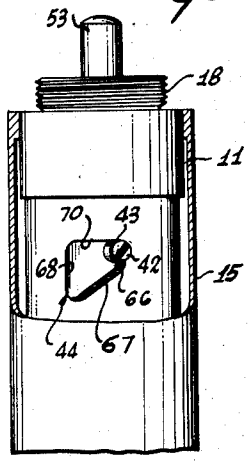


Fig. 3



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Fig. 4

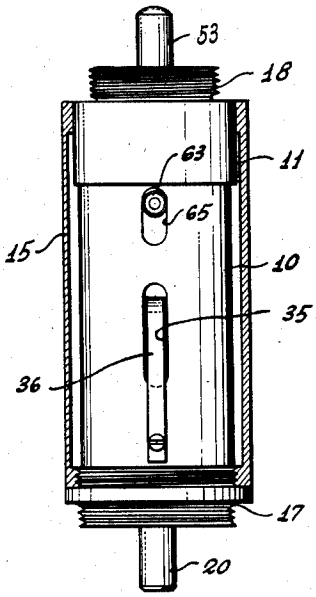


Fig. 5

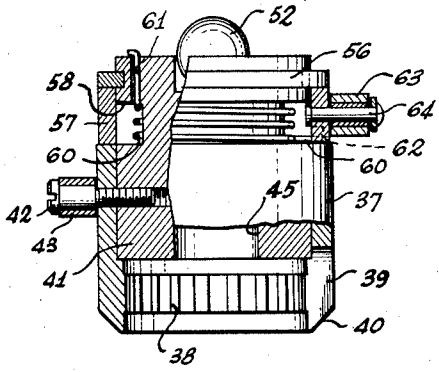


Fig. 6

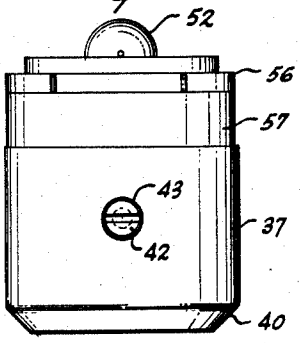
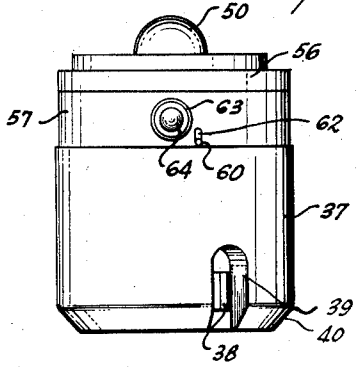


Fig. 7



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STEPPING DEVICE

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7 Claims. (Cl. 74—88)

This invention relates to a stepping device for angularly stepping a shaft in predetermined angular steps in response to repeated applications of a longitudinal actuating force to produce longitudinal movements of another part of the device.

Such a device is useful, for example, in operation of a multiple-position electric switch in which a contacting arm is turned successively into contact with various electric contacts arranged at angularly spaced locations. An electromagnet, or mechanical means such as a driven cam, may provide a longitudinally directed actuating force. Through the device of my invention such longitudinal actuating force may be applied to cause the switch arm to be rotated through a step of the proper angle, and the switch arm may be angularly stepped successively by each new longitudinal movement in response to the longitudinal force. Various other existing applications are those in which repeated longitudinal movements are required to be translated into step-wise angular movements. Such step-wise angular movements may be employed to position light filters or apertures for the passage and control of light or for other purposes.

It is, therefore, an object of my invention to provide a device for translating a longitudinal movement into a rotary movement.

An object of my invention is to provide a device for translating repeated longitudinal movements into successive step-wise rotary movements.

Another object is to provide a device for angularly stepping a shaft by predetermined angular steps in response to repeated applications of a longitudinal actuating force providing longitudinal movements of a part of the device.

Another object of the invention is to provide an angularly stepping device that, between steps, positively locks the shaft which is stepped.

An object of the invention is to provide a stepping device which cannot step or overstep due to shock, longitudinal acceleration forces, or centrifugal forces.

Another object is to provide a rotary stepping device of relatively very small diameter and which is ideally suited for miniaturization.

Another object is to provide a rotary stepping device that is capable of very precise movements and in which the moved part assumes very precisely predetermined positions.

Still another object of the invention is to provide a rotary stepping device that is capable of dependable operation over a very long period of use.

These and other apparent objects are attained in a manner that will be clear from consideration of the following description taken in connection with the accompanying drawings of which:

Figure 1 is a sectional view of the stepping device in the condition in which the shaft to be stepped is locked and prior to any movement of the longitudinally moving part, the section being taken along the line 1—1 of Figure 2;

Figure 2 is a sectional view through the device taken along the line 2—2 of Figure 1;

Figure 3 is a partial view of the device with the outside case cut away along the line A—A of Figure 2 and the device viewed from the left side thereof;

Figure 4 is a view of the device with the outside case cut away along the line A—A of Figure 2 and the device viewed from the right side thereof;

Figure 5 is an enlarged view, partially in section, of a portion of the device identified as the drive sleeve assembly;

Figure 6 is an enlarged view of the drive sleeve assembly viewed from the left in Figure 5; and

Figure 7 is an enlarged view of the drive sleeve assembly viewed from the right in Figure 5.

In the disclosed embodiment of the stepping device of my invention a generally cylindrical body **10** has attached to it at its upper end a cap **11** by means of threads **12**. Adjacent its lower end the body **10** is threaded at **13** and carries a flange **14**. In engagement with the threads **13** and abutting the flange **14** is the lower end of a protective case **15** which is guided at its upper end by the exterior surface **16** of the cap **11**. The lower end of the body **10** is externally threaded at **17** to connect with any device, such as a multiple-position rotary switch, which it is desired to have angularly stepped by the device of my invention. The upper end of the cap **11** is externally threaded at **18** to position the device appropriately with respect to the actuating mechanism such as an electromagnet or a cam.

The shaft which is stepped angularly by the stepping device is designated by the numeral **20**. The shaft **20** is mounted for rotation within ball-bearings **21** and **22** which are located within the lower cylindrical bore of the body **10**. The bearing **22** abuts an internal flange **23** in the body **10**. A spacer **24** separates the bearings **21** and **22**, and a nut **25** in engagement with internal threads **26** of the body **10** retains the bearings tightly assembled within the body **10**. The shaft **20** is enlarged at **27** above the bearing **22**, and a retaining collar **28** fitting over the shaft **20** and attached thereto by a set-screw **30** below the bearing **22** retains the shaft **20** in a fixed axial position. The shaft **20**, above the enlarged portion **27**, is still further enlarged at **31** and is splined to provide axially directed splines on its peripheral surface. A cylindrical portion **32** of the shaft **20** projects upwardly from the splined portion **31**. The shaft **20** is locked against rotation by engagement of a detent **33** with the externally splined portion **31**. The detent **33** is pivotally mounted on a pin **34** attached to the body **10** in a slot **35** thereof and is resiliently urged into engagement with the splined portion **31** by a flat spring **36**, thus forming a releasable means preventing rotation of the shaft **20**.

Slidable within the upper bore of the body **10** is a sleeve **37** which carries internal splines **38** which are adapted to mate with the external splines of the splined portion **31** upon movement of the sleeve **37** in the actuating direction (downward in Fig. 1). The sleeve **37** terminates at its lower end in a bevelled cam surface **40** which is adapted, upon continued downward movement of the sleeve **37**, to engage the angular upper end of the detent **33** to move it outwardly to disengage it from the splined portion **31**. Extending upward from the lower edge of the sleeve **37** is a slot **39** of a length somewhat greater than the downward travel of the sleeve **37** and a width slightly greater than that of the detent **33**. In the uppermost position of the sleeve **37** the slot **39** is angularly displaced from the detent **33** in a clockwise direction, as seen from below in Fig. 1 (or as shown in Fig. 2), by the angular amount of one spline of the splined portion **31**. Preferably pressed into the bore of the sleeve **37** and abutting a shoulder thereof is a cylindrical block **41** which is further secured to the sleeve **37** by a screw **42** having an enlarged head portion on which is rotatably mounted a cylindrical roller **43** which serves as a cam follower. The roller **43** is positioned so that it projects into and is movable within an aperture **44** in the

body 10 and is adapted to engage the walls of said aperture to guide the movement of the sleeve 37.

The block 41 contains an axial cavity 45 in its lower end into which the upper end 32 of the shaft 20 projects. A spring 46 bears at one end on the upper end of the shaft 20 and at the other end preferably on a cup 47 into which is set a ball 48. The ball bears on the end wall of the cavity 45 and is centrally located by an axial hole 50 which forms a seat for the ball. The hole 50 connects through to a cavity 51 in the upper side of the block 41 and seats a ball 52 residing in the cavity 51. A plunger 53 passes axially through a hole 49 in the cap 11 and carries an enlarged head 54 on its lower end which engages the ball 52. A snap ring 55 located in a groove in the plunger 53 limits the downward travel of the plunger 53 by abutment against the cap 11. If desired, the end of an electromagnet plunger or other force-actuated member may extend through the hole 49 and engage the ball 52 in place of the plunger 53 herein shown as part of the stepping device.

Rotatably mounted on the block 41 above the sleeve 37 and retained thereon by a snap ring 56 is a ring 57. Opposite the ring 57 is an annular recess 58 in the block 41 in which a spiral spring 60 is located, having one end secured to the block 41 by reason of being passed through a hole 61 in the block, and having the other end secured to the ring 57 by being passed through a slot 62 in the ring. The spring 60 causes the block 41, and therefore the sleeve 37, to be urged into counter-clockwise rotation with respect to the ring 57, as viewed from above in Fig. 5. To keep the ring 57 from rotating while still permitting axial, or longitudinal, movement of the block 41 and the sleeve 37 a roller 63 is rotatably mounted on a bearing collar pinned by a pin 64 to the ring 57, and is adapted to move in an axial direction within a groove 65 in the body 10, taking the rotational reaction of the spring 60 on the body 10.

The aperture 44 is specially shaped to provide the desired cam action on the follower roller 43 to guide the movement of the sleeve 37 in the desired manner. The right-hand wall 66 of the aperture, as viewed in Fig. 3, is, except for the corners, preferably substantially straight and of a length just slightly greater than the distance through which it is required to move the sleeve 37 downwardly to disengage the detent 33 from the splined portion 31. From the bottom of the wall 66 the aperture 44 slopes downwardly and to the left, as viewed in Fig. 3, along the wall 67, the angular travel of the roller 63 along the wall 67 as the roller is moved downwardly being substantially equal to the angular spacing of the splines on the splined portion 31. At the bottom of the sloping wall 67 the aperture is preferably formed with an arcuate corner of substantially the same radius as that of the roller 63. The left-hand wall 68 of the aperture 44 is preferably straight and of a length such that, as the roller 63 moves upwardly along it, it arrives at the top of the wall 68 at the same axial position as when it started at the top of the wall 66. The top wall 70 of the aperture is in a plane perpendicular to the walls 66 and 68 and the corners where the wall 70 meets the walls 66 and 68 are preferably formed arcuately with substantially the same radius as that of the roller 63.

The operation of the embodiment of the stepping device disclosed herein is as follows. Assume the plunger 53 to be in the unactuated position. The parts of the device are, therefore, in positions shown in Figure 1. Assume now that an axially directed longitudinal actuating force is applied in a downward direction to the plunger, as by an electromagnet, for example. The plunger 53, acting through the ball 52, pushes the drive member, including the block 41 and the sleeve 37, downward against the force of the spring 46. The bevelled lower end of the sleeve 37 engages the detent 33 and, upon continued downward movement, forces the detent out of engagement with the splined portion 31. By the time this has occurred, the internal splines 38 have meshed with the external splines 31, and the shaft 20 and the drive member are locked together for rotation, but the drive member is free to move in the axial direction relative to the shaft 20. During the downward movement of the drive member the roller 63 rides in the slot 65.

The follower roller 43 has moved downwardly along the straight wall 66 of the cam aperture 44 and is now at the start of the sloping wall 67 of the aperture. Continued downward movement of the plunger 53 pushes the roller 43 down along the sloping wall 67, causing the roller, and hence the drive member together with the shaft 20, to move angularly in a clockwise direction, as seen from above in Fig. 1. The detent 33 has moved up onto the cylindrical exterior of the sleeve 37. Further movement of the roller 43 to the bottom of the wall 67 results in completion of the angular step of the shaft 20 so that from the beginning of the action the shaft 20 has rotated through an angle equal to the angular spacing of the splines and the spline next to the one previously engaged by the detent 33 is now under the detent. Completion of this rotation has also brought the slot 39 under the detent 33 and the detent has fallen through the slot and engaged the underlying spline. At this stage the shaft 20 is again locked against rotation.

If, now, the longitudinal actuating force is removed from the plunger 53, the spring 46 pushes the drive member and the parts attached thereto upwardly in an axial direction, the drive member being guided in this direction by the meshing of the internal splines 38 with the splines 31. During this movement, the roller 43 moves upwardly along the wall 68.

When the splines 38 cease to mesh with the splines 31 the drive member, together with the roller 43, snaps back in a counter-clockwise direction, as viewed from above in Fig. 1, until the roller 43 engages the wall 66 of the aperture 44. The latter action takes place by reason of the torque exerted by the spring 60, the torque of which was increased when the drive sleeve assembly was caused to be rotated in the reverse direction by the cam action of the roller while traversing the sloping wall 67. The plunger 53 and all parts of the stepping device, except the shaft 20, are now back in the original positions ready for another cycle of operation as previously described.

The embodiment of the device herein shown and described is one in which the shaft 20 is angularly stepped in a counter-clockwise direction as viewed from below in Fig. 1; but it will be obvious that the device can be arranged to rotate the shaft in the clockwise direction instead. This can be accomplished by reversing the aperture 44 as to left and right in Fig. 3 so as to make the wall 67 slope downward and to the right, locate the slot 39 on the other side of the detent 33 in Fig. 2, and wind the spring 60 in the reverse direction.

The stepping device of my invention may be operated repeatedly in the manner hereinbefore rescribed at repetition rates of many per second. The device has, for example, been operated at rates up to 30 times per second with an angular rotation of the shaft 20 of 30 degrees per step. The device has been operated satisfactorily for millions of operations without attention and without failure.

It will be understood that various changes and modifications in design and construction of my stepping device may be made by those skilled in the art without departing from the spirit and scope of the invention defined in the appended claims.

I claim as my invention:

1. A stepping device for producing step-wise rotary movement of a shaft in response to repeated applications of a longitudinal actuating force, comprising: a body; means for supporting said shaft for rotation with respect to said body; releasable means preventing rotation of said shaft; a drive member supported by said body

for limited rotation about the axis of said shaft and for longitudinal movement along said axis, said drive member being adapted to be moved longitudinally toward said shaft by application of said longitudinal actuating force; means on said drive member and said shaft, effective upon longitudinal movement of said drive member toward said shaft, for rotationally connecting said drive member and said shaft and for cooperating with said releasable means to release said shaft for rotation; cam and follower means effective upon further longitudinal movement of said drive member to rotate said drive member and said shaft through a predetermined angle; means on said drive member, effective upon rotation of said drive member through said predetermined angle, to again make operative said releasable means preventing rotation of said shaft; means to longitudinally return said drive member after removal of said longitudinal actuating force; and means to rotationally return said drive member upon disconnection of said drive member from said shaft during the longitudinal return movement of said drive member.

2. A stepping device for producing step-wise rotary movement of a shaft in response to repeated applications of a longitudinal actuating force, comprising: a body; bearing means associated with said body rotatably supporting said shaft; a splined portion on said shaft; a detent carried by said body and engaging said splined portion to prevent rotation of said shaft; a drive member supported by said body for limited rotation about the axis of said shaft and for longitudinal movement along said axis, said drive member being adapted to be moved longitudinally toward said shaft by application of said longitudinal actuating force and to engage said detent during said longitudinal movement to disengage said detent from said splined portion of said shaft; a mating splined portion carried by said drive member and adapted to mate with said splined portion of said shaft, for rotation therewith, upon longitudinal movement of said drive member toward said shaft; cam means on said body for cooperation with a follower attached to said drive member to cause said drive member and said shaft to be rotated upon further longitudinal movement of said drive member toward said shaft; a slot in said drive member through which said disengaged detent can fall to again engage said splined portion of said shaft upon rotation of said drive member through a predetermined angle; a spring urging said drive member away from said shaft; and spring means, reacting upon said body, for rotationally returning said drive member upon disconnection of said mating splined portion of said drive member from said splined portion of said shaft during longitudinal return of said drive member toward its unactuated position.

3. A stepping device comprising, in combination: a body; a shaft having an externally splined portion; bearing means in said body retaining said shaft against axial movement but supporting it for rotational movement; a detent pivoting on said body and resiliently urged into engagement with said externally splined portion to prevent rotation of said shaft; a drive member axially slidable in a bore in said body and capable of limited rotation therein and having an internally splined portion adapted to mate with said externally splined portion of said shaft upon movement of said drive member in the actuating direction, the end of said drive member adjacent said detent being bevelled and adapted to engage said detent to disengage said detent from said externally splined portion upon continued axial movement of said drive member in said actuating direction; a cam follower projecting radially from said drive member; an aperture in said body into which said cam follower projects and providing cam surfaces engageable by said cam follower to rotate said drive member and said shaft in the operating direction upon further axial movement of said drive member in said actuating direction; a slot in said drive member through which said disengaged detent is adapted to fall to again engage said externally splined portion of said shaft upon rotation of said drive member through a predetermined angle; a spring urging said drive member in a direction opposite to said actuating direction; and spring means reacting upon said body for rotationally urging said drive member in a direction opposite to said operating direction.

4. A stepping device as claimed in claim 3, in which the spring urging said drive member in a direction opposite to said actuating direction is a spiral spring located in a recess in said drive member and bearing at one end on the end of said shaft.

5. A stepping device as claimed in claim 3, in which the spring means for rotationally urging said drive member in a direction opposite to said operating direction comprises: walls forming an annular recess in said drive member; a ring mounted for rotation on said drive member opposite said recess; a spiral spring encircling said drive member in said recess and having one end secured to said drive member and the other end secured to said ring; and a projecting member attached to said ring and projecting radially outward into a slot in said body to prevent rotation of said ring relative to said body.

6. A stepping device comprising, in combination: a generally cylindrical body; a shaft having an externally splined portion; bearing means in said body retaining said shaft against axial movement but supporting it for rotational movement; a detent pivoting on said body and adapted to engage said externally splined portion of said shaft; a spring urging said detent into said engagement with said externally splined portion of said shaft; a drive member axially slideable in a bore in said body and capable of limited rotation therein and having an internally splined portion adapted to mate with said externally splined portion of said shaft upon movement of said drive member in the actuating direction, the end of said drive member adjacent said detent being bevelled and adapted to engage said detent to disengage said detent from said externally splined portion of said shaft upon continued axial movement of said drive member in said actuating direction; a cam follower projecting radially from said drive member; an aperture in said body into which said cam follower projects and providing cam surfaces engageable by said cam follower to rotate said drive member and said shaft in the operating direction upon further axial movement of said drive member in said actuating direction; a slot in said drive member through which said disengaged detent is adapted to be forced by said spring which is in contact therewith to again engage said externally splined portion of said shaft upon rotation of said drive member through a predetermined angle; an axially directed recess in the end of said drive member adapted to receive the end of said shaft; a spiral spring located in said recess and bearing upon the end of said shaft to urge said drive member in a direction opposite to said actuating direction; spring means reacting upon said body for rotationally urging said drive member in a direction opposite to said operating direction; a cap attached to the end of said body adjacent said drive member having a hole therethrough; and a plunger passing through said hole in said cap and adapted to act upon said drive member when moved axially in said actuating direction.

7. A stepping device as claimed in claim 6, in which the spring means for rotationally urging said drive member in a direction opposite to said operating direction comprises: walls forming an annular recess in said drive member; a ring mounted for rotation on said drive member opposite said recess; a spiral spring encircling said drive member in said recess and having one end secured to said drive member and the other end secured to said ring; and a projecting member attached to said ring and projecting radially outward into a slot in said body to prevent rotation of said ring relative to said body.

No references cited.