United States Patent

Loughran, Jr.

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[54] **ROTARY ACTUATOR AND INDICATOR**

[72] Inventor: **Eugene F. Loughran, Jr.,** Oakville, Conn.

[73] Assignee: **North American Philips Corporation,** Waterbury, Conn.

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[52] **U.S. Cl.** 335/272

[51] **Int. Cl.** H01h 50/18

[58] **Field of Search** 335/272, 125, 138; 340/373

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Primary Examiner—Harold Broome
Attorney—Donald P. Gillette

[57] **ABSTRACT**

An indicator having an armature with spaced magnetic poles mounted to pivot back and forth on its axis to match indicia on the armature with fixed indicia at each end position of the pivotal motion. The armature poles are attracted alternately to the two end positions by stator poles energized by a coil supplied with current that corresponds in magnitude or direction of flow with the operating condition under surveillance. Pivotal motion of the armature is limited by a pin, either on the armature or on the stator, that fits into an annular slot in the stator or armature. The armature can move axially to a limited extent, and to hold the disc in either of its limit positions, the ends of the slot are further axially indented to receive the pin. The armature is free to move axially far enough to disengage the pin from the indentations but not completely free of the slot.

15 Claims, 10 Drawing Figures

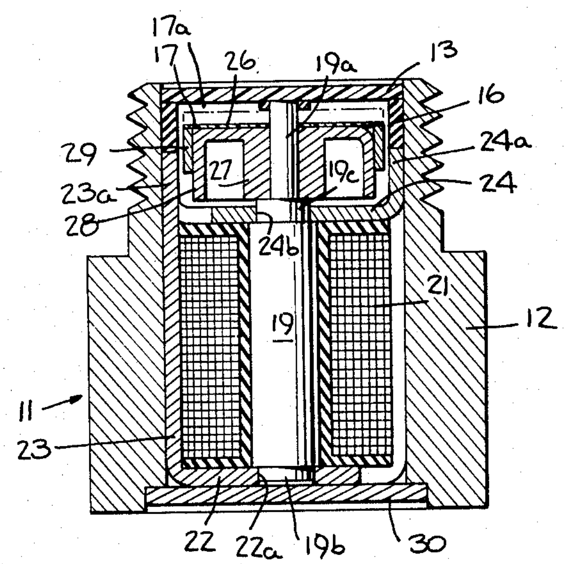


FIG. 1.

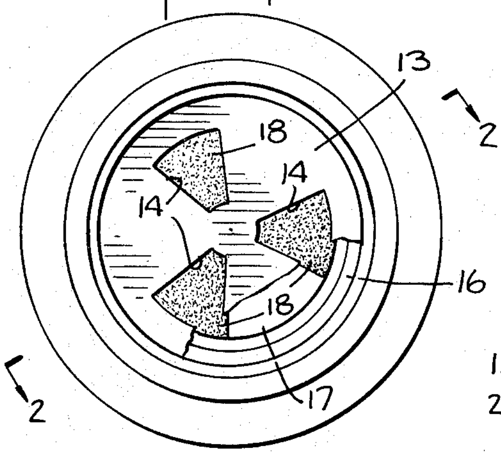


FIG. 2.

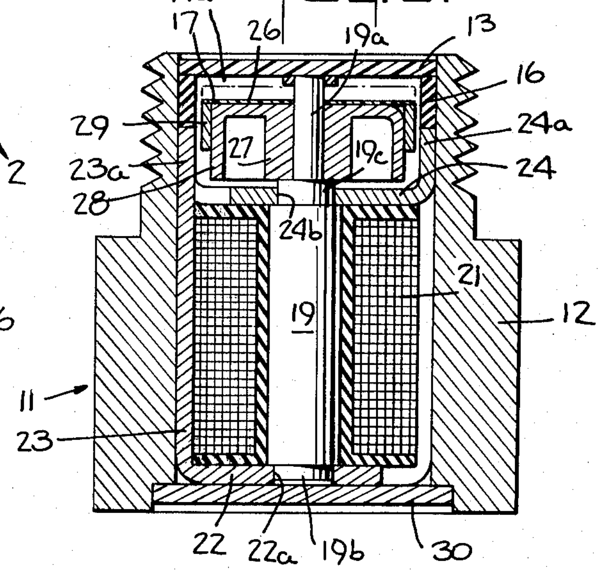
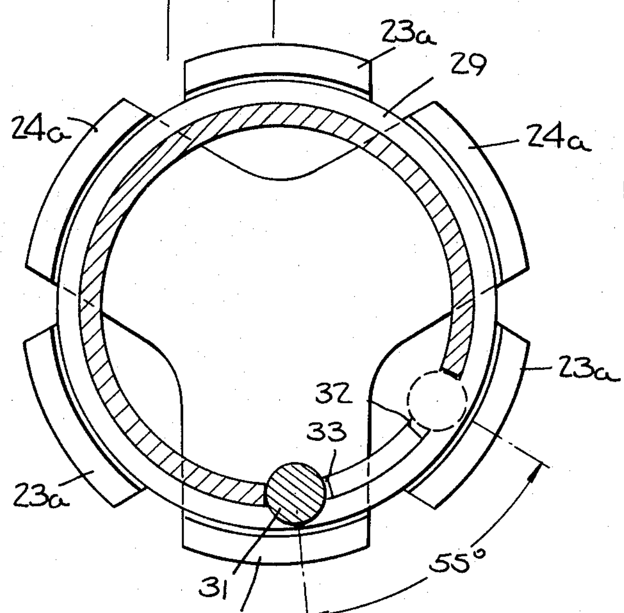


FIG. 5.



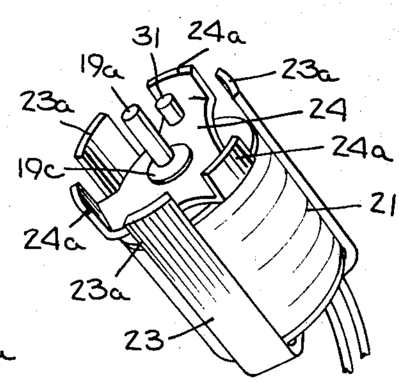


FIG. 3.

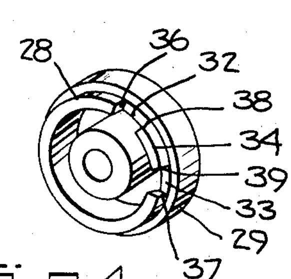
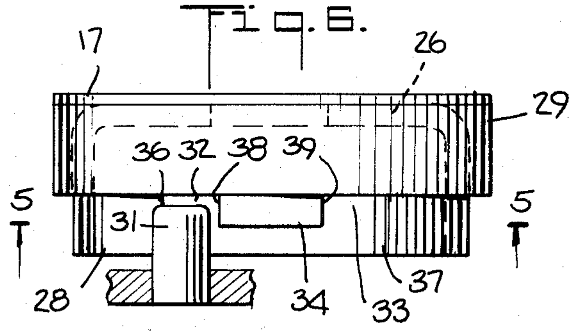


FIG. 4.

FIG. 6.



INVENTOR.
EUGENE F. LOUGHRAN, JR.
BY
[signature]
ATTORNEY

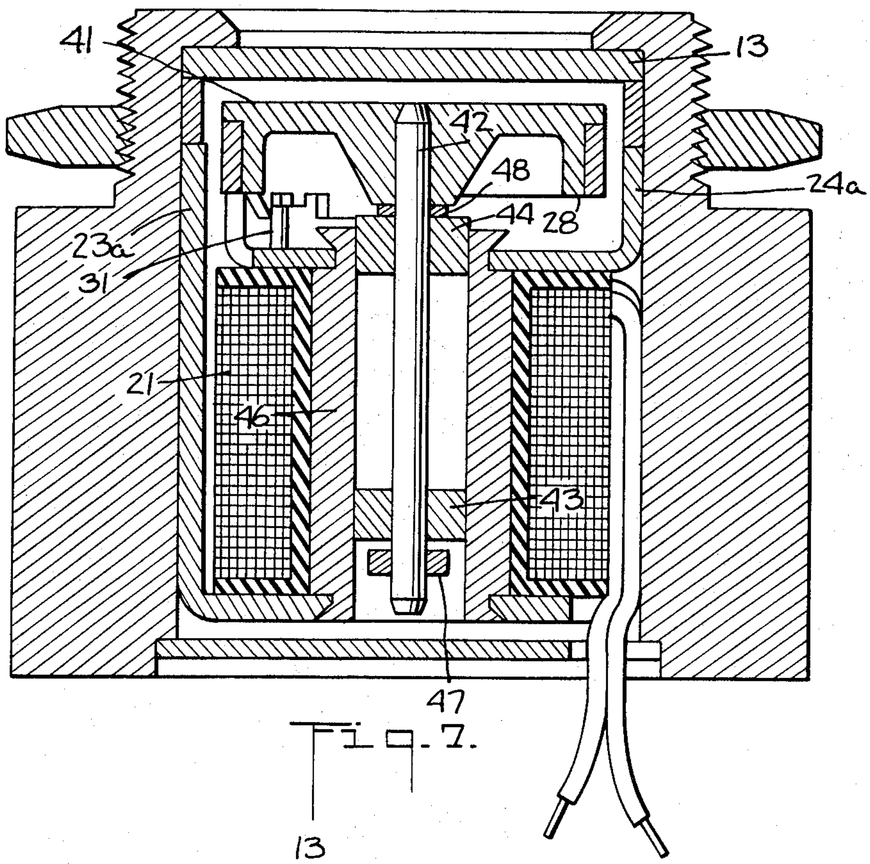


Fig. 7.

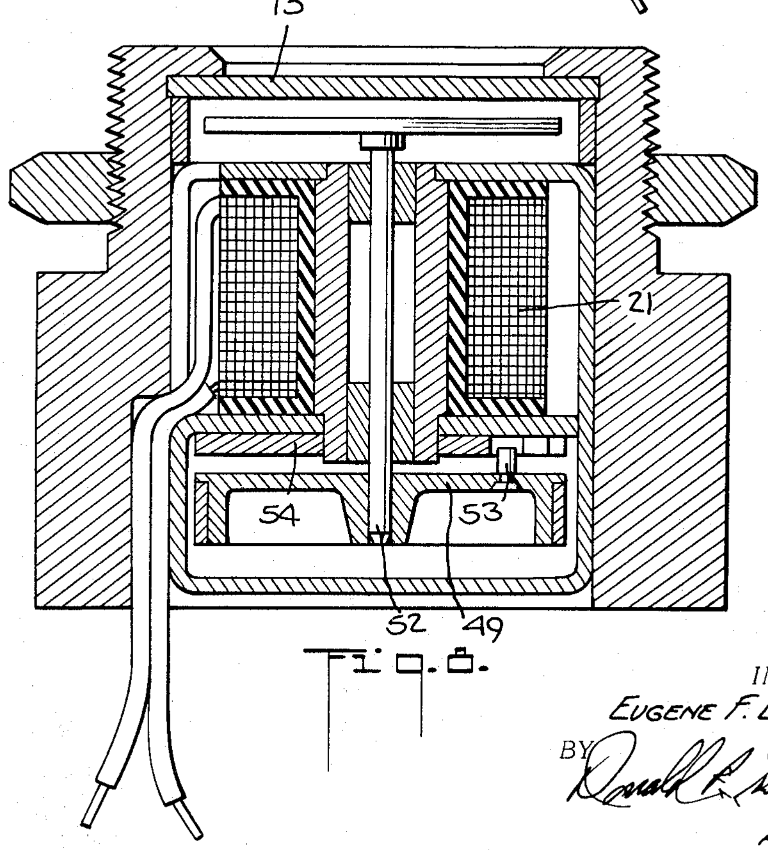


Fig. 8.

INVENTOR.
EUGENE F. LOUGHRAN, JR.
BY [signature]
ATTORNEYS

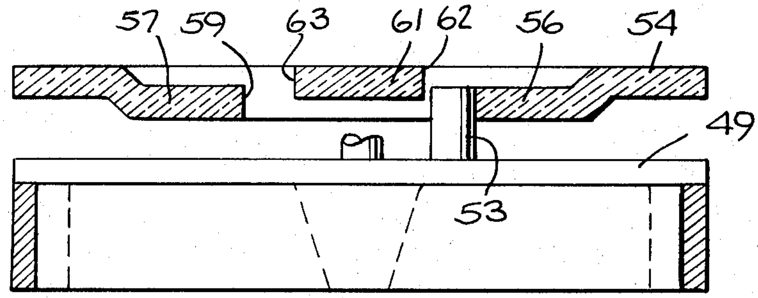


Fig. 9.

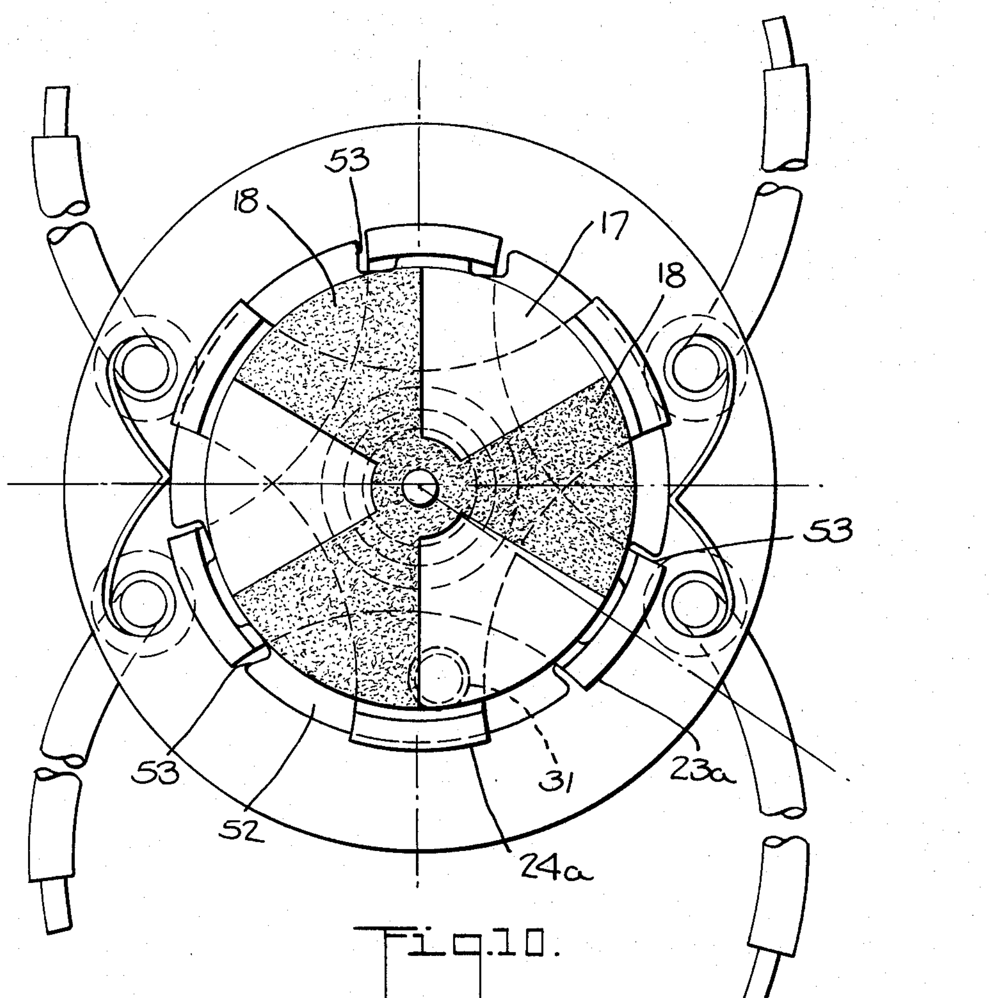


Fig. 10.

INVENTOR.
EUGENE F. LOUGHRAN, JR.
BY [signature]
ATTORNEY

ROTARY ACTUATOR AND INDICATOR

This invention relates to an actuator and an indicator operating in a rotary, or pivotal, motion between fixed limits. In particular it relates to an actuator that has an armature that moves axially between a quiescent position and an energized position, with means to rotate the armature from one angular limit to the other.

In the field of built-in test equipment there is a continual effort to reduce the size, complexity, and power requirements of indicators that have two indicating positions to show that the equipment under test is in one or the other of two conditions, for example, either operative or inoperative. Moreover, the indicators must be as free as possible from giving spurious, ambiguous, or incorrect responses. This means, among other things that the indicator must not jump out of position due to mechanical shock, to which such indicators are frequently subjected in the environment in which they are operated.

In accordance with these requirements, the present invention comprises an indicator having a rotary actuator operated electromagnetically. The actuator comprises a coil, stator pole members magnetically energized when the coil carries current, and an armature to which indicia may be attached. The armature has permanent magnetic poles that align with the stator in one of two ways, depending on the direction of current flow in the coil. When the armature and its attached indicia are in one angular position, an alignment between the indicia and a fixed identification structure establishes that the armature is in that particular position which corresponds to one condition of the equipment under test. Reversal of the armature to the other position results in visual indication of movement of the armature and therefore of the fact that the equipment under test has shifted to the other condition.

In order to limit the movement of the armature to just two positions and to hold it in either of those positions when the coil is not energized, either the armature or the stationary part of the device has two main abutments that engage stop means on the other part of the device. Two additional abutments cooperate with stop means to hold the armature in either end position after the coil has been transferred to that position. Magnetic attraction between the permanently magnetized poles of the armature and the stator poles holds the armature axially in position so that the stop means engages the appropriate abutments until a net current in the reverse direction so magnetizes the stator poles that the armature poles are repelled. The armature first moves to disengage the abutments from the stop means, after which the armature is free to rotate to the alternative position under the combined magnetic forces of the stator and rotor poles. Once the armature reaches the alternative position, the abutments and stop means will again engage and force the armature to remain in place due to the attraction between the stator poles and the armature poles. Even after the current through the coil has been cut off, the armature will remain in that position due to the magnetic attraction of the permanently magnetized armature poles for that set of stator poles. The armature cannot easily be shaken out of position because it would require a combined axial and rotary motion to dislodge it.

The invention will be further described in the following specification together with the drawings in which:

FIG. 1 is a front elevational view of an indicator constructed according to the invention with parts broken away to show the interior construction thereof;

FIG. 2 is a cross-sectional side view of the indicator of FIG. 1;

FIG. 3 is a perspective view of the stator structure of the indicator of FIG. 2;

FIG. 4 is a perspective view of the movable member of the indicator in FIG. 1;

FIG. 5 shows the angular relationship between the stop on the stator structure and the abutments on the movable member of the indicator;

FIG. 6 is a side view of the movable member and the stop on the stator structure of FIG. 5.

FIG. 7 is a cross-sectional view of a different embodiment of the invention;

FIG. 8 is a cross-sectional view of another embodiment of the invention;

FIG. 9 is a cross-sectional view of the latching plate in FIG. 8; and

FIG. 10 is a plan view of the indicator showing certain angular relationships.

The indicator 11 in FIG. 1 comprises an outer shell 12 having a generally opaque face 13 with three wedge-shaped windows 14 equally spaced around the center of the face 13. Part of the face has been broken away to show some of the internal features of the indicator including a spacer 16 on which the is supported and the disk 17 immediately behind the face. The disk has three wedge-shaped flags 18 spaced to correspond to the electromagnetic driving unit comprising a central ferromagnetically soft steel core 19 on which a stator coil 21 is mounted. At one end of the core 19 is a soft steel disk 22 having several integral strips 23 extending up alongside the coil 21 and terminating in pole portions 23*a*. Near the other end of the core 19 is another ferromagnetically soft steel disk 24 having another set of stator poles 24*a* extending from its edge in the same direction as the pole portions 23*a*. The spacer 16 rests on top of all of the stator poles 23*a* and 24*a*.

The movable part of the indicator includes a support member 26 having a central bearing 27 supported on an extension 19a of the core 19. The outer perimeter of the support 26 has a downwardly turned rim 28 and the disk 17 is directly affixed to the upper surface of the support member 26. A permanently magnetized ring 29, which may be an elastomeric material, is attached to the outer surface of the rim 28 to provide the necessary magnetic field or fields to interact with the stator poles 23*a* and 24*a* to move the support member 26. The core 19 also helps to space the various members of the electromagnetic driving unit properly within the shell 12. The lower end of the core has a portion 19*b* of reduced diameter to fit snugly into a central hole 22*a* in the disk 22. Near the upper end of the core 19 is another portion of reduced diameter 19*c* which fits snugly into a matching hole 24*b* in a disk 24, and the uppermost end of the extension 19*a* abuts against the inner surface of the face 13. A cap 30 closes and seals the lower end of the shell 12 to keep out dirt and contaminating vapors.

One of the reasons for providing specific spacing within the shell 12 is to permit a limited amount of axial movement of the movable member, including the support member 26, to allow the disk 17 to shift to the position indicated in dot-and-dash lines and identified by reference numeral 17*a*. The purpose of providing for this limited axial movement of the movable member will be explained in connection with FIGS. 3–6.

FIG. 3 shows a perspective view of the electromagnetic driving unit and in this figure it may be clearly seen that there are three equally spaced stator poles 23*a* and three equally spaced stator poles 24*a* spaced midway between the poles 23*a*. Near the outer part of the disk 24 is a vertical stop pin 31 which limits the angular movement of the support member 26 by engaging abutment edges therein.

The movable member is shown in FIG. 4 and it includes two notches 32 and 33 in the rim 28. Between the two notches is a section 34 of reduced height, which is to say that the abutment edges 36 and 37 of the notches 32 and 33, respectively, are axially somewhat longer than the abutment edges 38 and 39 of those same notches.

Surrounding the rim and firmly bonded thereto is the permanently magnetized rotor ring 29 which has, in this embodiment, six poles, three of which are north poles and three of which are south poles. The poles are arranged alternately north and south around the ring 29 and the ring is magnetized so that one of the north poles has its center line on one of the abutment edges, in this case the abutment 36. This produces the desired holding effect to keep the rotor assembly in place. The ring 29 may be made of a rubberlike material containing ferrite to allow it to be permanently magnetized.

FIG. 5 shows the angular spacing between the notches 32 and 33 relative to the angular spacing between permanently magnetized pole areas of the ring 29. In the embodiment shown there are six permanently magnetized pole areas, three of which are north pole areas and the other three of which are south pole areas, all equally spaced around the ring 29. The angular dimensions of the notches 32 and 33 and their spacing of about 53° between their centers is such that, taking into account the diameter of the stop pin 31, the support member 26 is able to move only approximately 55° which is slightly less than the spacing between adjacent poles 22*a* and 24*a* in the ring 29. Since the normal magnetic attraction of the permanently magnetized poles in the ring 29 with respect to the stator poles 23*a* and 24*a* is such that the ring attempts to pull the support member 26 farther than is permissible, the limitation of movement of the support member to only 55° means that when either of the notches 32 and 33 engages the stop pin 31, there is a residual magnetic force that holds the support member 26 so that either the abutment edge 36 of the abutment edge 37 presses against the pin 31. The angular width of notches 32 and 33 is slightly greater than the angle necessary to allow the pin 31 to fit into the notches. As a result there is a slight space between the abutment edges 38 and 39 and the pin 31 when the notches 32 and 33, respectively, fit over the end of the pin.

While the spacing between the three poles 23*a* is 180° and the spacing between the three poles 24*a* is 180°, the poles 23*a* are slightly displaced with respect to the poles 24*a* so that the spacing of adjacent poles are alternately 57° and 63°. This has been found to increase the axial thrust about 10 to 15 percent over what the thrust would be with equal axial spacing between each pole 23*a* and the poles 24*a* on each side of it.

The interfitting of the pin 31 into the notches 32 and 33 is shown in FIG. 6 where the pin is within the notch 32. FIG. 6 also shows the axial spacing between the bottom edge of the rim 28 and the edge 34. In effect, the entire space between the abutment edges 36 and 37 may be considered to be a relatively side slot with two deeper but narrower notches 32 and 33 at the ends.

The operation of the electromagnetic driving unit is such that the permanent magnetic fields of the poles in the ring 29 cause the ring 29 and therefore the support member 26 to be attracted axially toward the ends of the stator poles 23*a* and 24*a* when no current is applied to the coil 21. When current is applied to the coil 21 to magnetize the stator poles 23*a* and 24*a* with the proper magnetic polarities to rotate the movable member, this same magnetic field relationship repels the poles in the ring 29 axially toward the face 13 so as to place the disk 17 in the position 17*a* in FIG. 2. This movement is sufficient to permit the end of the pin 31 to clear the edge 34, as may best be seen by reference to FIG. 6, but not beyond the edges 36 and 37, that is, not beyond the bottom edge of the rim 28. Simultaneously, the effect of the magnetic fields of the stator poles 23*a* and 24*a* is such as to rotate the ring 29 and hence the support member 26 to the alternative position. With reference to FIG. 6, this would be the position in which the notch 33 would be over the pin 31. As long as the coil 21 remains energized with that polarity, the support member 26 will be in position to have the notch 32 engage the pin 31. Moreover, even after energizing current has been removed from the coil 21, the axial magnetic attraction between the permanent poles in the ring 29 and the stator poles 23*a* and 24*a* will be such as to maintain the support member 26 in the same angular position but axially retracted as shown in solid lines in FIG. 2. In this position the stop pin 31 engages sufficiently deeply into the notch 33 so that the abutment edge 39 would prevent the support member 26 from turning even if the indicator 11 were subjected to a rotary shaking action of sufficient force to overcome the magnetic force of attraction between the poles in the ring 29 and the stator poles 23*a* and 24*a*. Before the movable member could be moved to its alternative position, there would have to be, in addition to the rotary shaking motion, an axial shaking motion occurring at the same time. This is the type of motion that would be necessary to allow the barrier formed by the abutment edges 38 and 39 and the edge 34 to jump over the stop pin 31.

The embodiment in FIG. 7 includes many of the same parts as the embodiment in the earlier figures and it is therefore unnecessary to describe these parts in detail. However, while the movable part of the indicator in FIG. 2 is shown supported on a fixed extension 19*a*, the movable member, or armature, 41 in FIG. 7 is affixed to a rotatable shaft 42 which in turn is supported in bearings 43 and 44 spaced apart along a hollow core 46 that extends through the coil 21. The shaft 42 is free not only to rotate in the bearings 43 and 44 but also to slide longitudinally. A retaining washer 47 is attached to the other end of the shaft to limit the extent of longitudinal movement and a thrust washer 48 is placed on the shaft between the armature 41 and the bearing 44.

The stator poles 23a and 24a are arranged in the same configuration as in FIG. 3 and the same stop, or index, pin 31 is provided to limit the rotation of the armature 41 by engaging in a notched latching section of the downwardly turned rim 28 of the armature 41. The latching section has the same notches 32 and 33 and the same abutment edges as the armature shown in FIG. 6.

The operation of the embodiment in FIG. 7 is nearly the same as the operation of the embodiment in FIG. 2, except that the whole shaft 42 moves longitudinally and rotates instead of just the armature 41. Indicia on the surface of the armature 41 are visible through windows in the face 13 to indicate whether the armature 41 is in one of the other of its end positions.

The embodiment in FIGS. 8 and 9 differs in that it has an armature 29 at one end and an indicator disk 51 at the other end of an elongated rotor shaft 52. This shaft is supported by the same bearings 43 and 44 as the shaft 42 in FIG. 7 but it is unnecessary to provide a retaining washer since the indicator disk 51 serves that purpose.

Instead of providing a fixed stop pin, as in the earlier embodiment, the embodiment in FIG. 8 has a stop pin 53 affixed to the armature 52 and engaging an index plate 54. The relationship between the armature 49 and the stop pin 53 and the plate 54 is better shown in FIG. 9 where it may be seen that the index plate has two portions 56 and 57 pressed out of plane of the remainder of the plate 54 and toward the armature 49. A slot is formed between these portions 56 and 57 and the edges of these portions form abutment edges 58 and 59 which limit the maximum arcuate movement of the armature 49. Between the portions 56 and 57 is another portion of the plate 54 indicated by reference numeral 61. This portion does not extend upwardly as far as the portions 56 and 57 but its side edges 62 and 63 do form abutment edges that capture the pin 53 in either of its positions in a manner similar to the capture of the pin 31 in FIG. 6. The space 64 between the abutment edges 58 and 62 corresponds to the notch 32 in FIG. 6 and the space 66 between the abutment edges 59 and 63 corresponds to the notch 33 in FIG. 6.

The operation of the structure in FIGS. 8 and 9 is, insofar as the latching is concerned, the converse of the operation of the other embodiment. In this instance the stop pin is on the rotor and the notches and abutment edges are on the stationary part of the device, whereas in the previous embodiment it was just the reverse. However, the armature 49 does follow the same longitudinal and rotary motion as the movable member 26 in the embodiment in FIGS. 1–6.

The embodiment in FIGS. 8 and 9 has an additional advantage due to the fact that in the quiescent position with the stop pin in either of the notches 64 and 66, the rotor 49 is drawn longitudinally toward the coil 21 which causes the indicator disk 51 to move close to the face 13 through which indicia on the indicator disk 51 are to be observed. On the other hand, in the quiescent condition of the embodiment of FIG. 2, for example, the indicator disk 17 is as far away from the face 13 as the available space permits. As a result there is less parallax in the embodiment in FIG. 8 than in the embodiment in FIG. 2 during the important intervals of time when the disk 51 is in one of its two indicating positions. The reduction in parallax means that the indicia on the disk 51 match more closely the indicia of the face 13.

FIG. 10 shows the angular relationship between the poles 23*a* and 24*a*, the stop pin 31, and the indicia 18. As may be noted, the poles 24*a* are displaced counter-clockwise 3° with respect to the poles 23*a*. Also shown in this figure is an end plate 52 with notches 53 to position the poles 23*a*. The three indicia sectors each have an included angle of 60°, and the counter-clockwise edge of each is on the center line of one of the poles 24a when the indicator disk 17 is in the counter-clockwise position shown.

What is claimed is:

1. A rotary actuator comprising: a coil, an armature to be rotated over a range of positions between first and second end positions; a shaft pivotally supporting said armature; first and second stator poles members magnetically coupled to said coil to be mutually oppositely magnetically energized thereby and having angularly spaced stator poles; stop means fixed with respect to said pole members; first and second abutments on said armature to engage said stop means to limit angular movement of said armature to said range of positions; third and fourth abutments to engage said stop means to maintain said armature in either of said end positions when said coil is not energized; and a permanently magnetized section on said armature magnetically coupled to said stator poles, said armature being axially movable to disengage said third and fourth abutments from said stop means when coil is energized to magnetize said stator poles to shift said armature from one of said end positions to the other.

2. The actuator of claim 1 in which said armature comprises a disk and said abutments comprise slotted edge portions thereof.

3. The actuator of claim 2 in which said disk has an axial flange and said slotted edge portions are axial slots in said flange.

4. The actuator of claim 2 in which said slotted edge portions comprise a main angular slot, the ends of which form said first and second abutments, and said stop means comprises an axially extending member within said slot and having an axial length greater than the maximum axial movement of said armature.

5. The actuator of claim 2 in which said edge portions comprise an axial flange having an angular slot therein defined between first and second axially extending walls forming said first and second abutments, said slot being axially deeper at each end than in the middle thereof and defined by an edge having third and fourth walls facing said first and second walls, respectively but shorter axially, than said first and second walls and forming said third and fourth abutments, said stop means comprising an axial projection having a small enough angular width to fit between said first and third abutments or between said second and fourth abutments.

6. The actuator of claim 1 in which said shaft is a ferromagnetically soft cylinder extending through said coil and comprising a core therefor.

7. The actuator of claim 6 in which said shaft extends through said coil and said first and second stator pole members are affixed to opposite ends of said shaft.

8. The actuator of claim 7 in which said stop means comprises an axial pin affixed to one of said stator pole members.

9. The actuator of claim 7 in which said first stator pole member has a plurality of evenly spaced stator poles extending therefrom axially along the outer surface of said coil and said second stator pole member has a corresponding plurality of evenly spaced stator poles interleaved with the ends of the stator poles from said first stator pole member.

10. The actuator of claim 9 in which said first and second end positions of said armature are angularly spaced apart by a smaller angle then the angle between the center of a pole from said first stator pole member and the center of the adjacent pole from said second stator pole member.

11. The actuator of claim 1 comprising, in addition: an indicator attached to said armature to move therewith and having angularly spaced indicia thereon; and a cover over said indicator and having window means through which said indicia may be seen when said armature is in said first end position but not when said armature is in said second end position.

12. A rotary actuator comprising: a coil, stator pole means magnetically coupled to said coil; an armature rotatable between first and second angular positions and comprising permanently magnetized poles, said armature also being free to move axially a predetermined distance from one axial position when said coil is energized to an opposite axial position when said coil is not energized; latching means to hold said armature in either of said positions, said latching means comprising a stop, first and second abutments to engage said stop to fix the maximum angular movement of said armature, and third and fourth abutments between said first and second abutments and spaced therefrom whereby said stop may fit between said first and third abutments in one of said positions and between said second and fourth abutments in the other of said positions, said third and fourth abutments having a smaller axial dimension than the extent of movement of said armature whereby said armature can move past said third and fourth abutments when said coil is energized to magnetize said stator poles to shift said armature from one of said angular positions to the other.

13. The actuator of claim 12 in which said stop is affixed to said stator pole means.

14. The actuator of claim 12 in which said stop is affixed to said armature.

15. The actuator of claim 12 in which said stop extends axially from said armature and said actuator comprises, in addition, a substantially planar index plate having portions raised above the plane of said plate and having edges comprising said first and second abutments, said plate having an additional portion between said raised portions, said additional portion having edges defining said third and fourth abutments.

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