

Oct. 16, 1956

E. V. NAYBOR

2,767,357

ELECTROMAGNETIC ACTUATOR

Filed Sept. 10, 1952

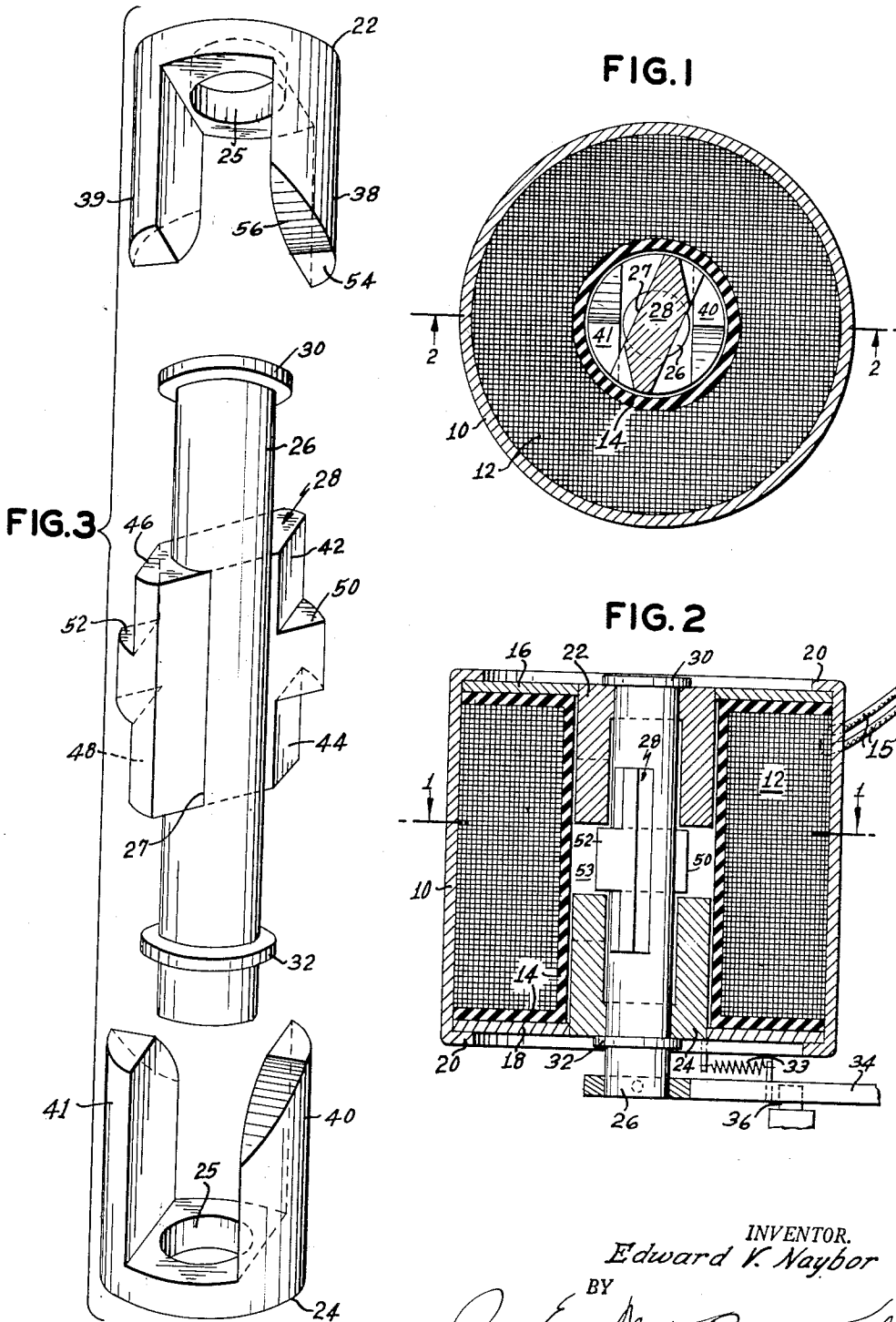


FIG. 1

FIG. 2

FIG. 3

INVENTOR.

Edward V. Naybor

BY

Pennig, Edwards, Morton, Carrows and Taylor
ATTORNEYS

1

2,767,357

ELECTROMAGNETIC ACTUATOR

Edward V. Naybor, Malverne, N. Y., assignor to Molyneux & Aspinwall, Inc., Port Washington, N. Y., a corporation of New York

Application September 10, 1952, Serial No. 308,853

11 Claims. (Cl. 317—197)

This invention relates to improvements in electromagnetic actuators having an armature which is adapted to be rotated through a given arc or angle and thereby actuate a control device or mechanism.

Actuators of the type under consideration are particularly useful for the remote actuation of various types of controls, such as electric switches, valves, indicators, rheostats and other devices.

The primary object of the present invention is to produce a rotary electromagnetic actuator in which the pole pieces and armature have a relationship adapted to produce a maximum magnetic flux when the coil of the actuator is energized.

A further object of the invention is to provide a rotary electromagnetic actuator which is adapted to create a relatively constant torque through a large angular displacement and in which the armature has a low moment of inertia.

Another object of the invention is to provide a rotary electromagnetic actuator which has adequate power for ordnance applications, has relatively small dimensions and which is not affected in its operation by severe vibration or shock.

I have discovered that an effective rotary electromagnetic actuator can be provided by locating the armature air gap in the center of the core of the coil of the actuator between a pair of pole pieces which extend from opposite ends of the coil axially into the opening formed by the coil. In this construction, the armature is arranged in overlapping relation to both pole pieces so that maximum flux passes through the armature when the coil is energized and it engages both pole pieces.

In accordance with the invention, the improved actuator includes an actuating coil having an axial opening, a pair of similar fixed pole pieces of ferro-magnetic material extending into the opening of the coil respectively from the opposite ends of the coil. In this construction, the inner-ends of the pole pieces are spaced apart to provide an air gap in the center of the coil. The actuator also includes a rotatable shaft of non-magnetic material extending axially through the coil and the pole pieces, each pole piece including similar spaced inner end portions on opposite sides of the shaft having similar plain or flat surfaces parallel to each other and to the shaft, and an armature of ferro-magnetic material carried by the shaft and extending into the spaces between the opposite plain surfaces of both pole pieces and being rotatable therein with the shaft when the coil is energized.

In a preferred construction, the air gaps between the pole pieces are arranged in the most central section of the core of the electromagnet, in order to provide maximum efficiency, minimum inertia, and complete balance. In this construction, the inner-end portions of the pole pieces are tapered toward the base, from the armature air gap or gaps so as to provide maximum flux density at the armature air gap, and the armature is provided with a step-like section or projection which extends part-

2

ly into the air gap between the pole pieces in the unenergized position of the armature and which moves completely into the gap between the pole pieces when the actuator is energized. In the unenergized position, the step or steps provide a magnetic shunt which increases the initial pull on the armature.

The improved actuator of the present invention includes other features and advantages which are described in detail hereinafter in connection with the accompanying drawings forming a part of this application.

In the drawings:

Fig. 1 is a horizontal sectional view of the improved electromagnetic actuator taken on the line 1—1 of Fig. 2 showing the rotor shaft and armature in its unenergized position;

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

Fig. 3 is an exploded view in perspective of the rotor shaft, armature and the pole pieces associated therewith.

Referring to Figs. 1 and 2 of the drawings, the improved actuator comprises an outer cylindrical shell or casing 10 surrounding a copper wire coil 12 wound on a coil bobbin 14 of insulating material providing an axial opening through the coil. Conductors 15 supply electric current to the coil 12. The coil and bobbin are held in place in the casing 10 by means of annular end plates 16 and 18, the ends of the casing being flanged over the periphery of the end plates at 20. A pair of similar fixed pole pieces 22 and 24 having cylindrical shaped outer ends or bases are fitted in the axial openings in the end plates 16 and 18, respectively, and fixed therein in the positions shown in Fig. 2. The casing 10, the end plates 16 and 18, and the pole pieces 22 and 24 are of ferro-magnetic material.

The outer-end portions of the pole pieces 22 and 24 are provided with axial openings 25 (Fig. 3) which serve as bearings for the rotor shaft of the actuator, which comprises a non-ferrous or non-magnetic shaft 26 provided with a slot 27 intermediate its ends in which is located a ferro-magnetic armature 28. The shaft 26, as shown, includes a head 30 bearing against the base of the pole piece 22 while its opposite end portion is provided with a retaining ring 32 which bears against the base of the pole piece 24 to prevent endwise movement of the shaft.

In Figs. 1 and 2, the armature 28 is shown in unenergized position with respect to the pole pieces, which position is normally maintained by means of a spring 33 biasing an actuating arm 34 against a stop 36. The arm 34 is fixed to the lower projecting end of the rotor shaft 26 and is normally employed for actuating an electric switch, relay valve, or other mechanism.

The structure of the pole pieces and armature and their relationship with respect to each other is shown in Fig. 3 of the drawings, in which it will be seen that each pole piece includes similar spaced inner-end portions which extend on opposite sides of the rotor shaft, the pole pieces together forming a slot within which the armature operates. The pole piece 22, for example, includes inwardly-projecting segments or portions 38 and 39, while the pole piece 24 includes similar projections or segments 40 and 41. These pairs of segments have inside plain or flat surfaces which are parallel to each other and to the shaft for engagement by surfaces of the armature, the respective flat surfaces of one pole piece being in the same plane as the corresponding surfaces of the other pole piece.

The armature 28 comprises a block of metal adapted to operate freely inside the opening in the bobbin between the pairs of projecting inner-end portions 38, 39, 40 and 41 of the pole pieces. From the showing in Fig. 3, it will be seen that the armature block is generally rectangu-

lar in shape and is cut to include a pair of flat beveled surfaces 42 and 44 at one side and a pair of similar surfaces 46 and 48 at the opposite side. The surfaces 42 and 44 are in the same plane and the same is true of the surfaces 46 and 48, the two pairs of surfaces being parallel to each other. When the actuator is energized, the surfaces 42 and 46, respectively, engage the inside surfaces of the pole segments 38 and 39, while the surfaces 44 and 48 respectively engage the inside surfaces of the pole segments 40 and 41. In each instance, the respective surfaces engaged are diagonally opposite each other, as will be apparent from the showing in Fig. 1 of the drawings. For example, the surface 44 engages the far inside portion of the segment 40, as seen in Fig. 3, while the surface 48 engages the near inside portion of the segment 41.

The armature 28 also includes diagonally opposite steps or projections 50 and 52, intermediate the ends of the armature, which are left when the beveled contact surfaces are formed. These projections 50 and 52 respectively move completely into the air gap 53 (Fig. 2) between the pole pieces 22 and 24 when the actuator is energized. The step-like sections or projections 50 and 52 extend partly into the air gap in the unenergized position of the armature, as seen in Fig. 1. This arrangement provides a magnetic shunt which increases the initial pull on the armature when the actuator is energized. The shape and number of such steps or projections can be varied to obtain different degrees of torque at various angular displacements from the closed position of the armature.

Another feature of the invention is the shape of the segments of the pole pieces 22 and 24, as illustrated in Fig. 3 of the drawings. Each of the four segments are tapered away from the inner end of the segment, or from the opposite pole piece, toward the base of the segment beginning at about the middle of the end of the segment. This tapering is effected on the side or portion of the segment not engaged by the armature surface, as will be apparent from the showing in Fig. 3. For example, note that the segment 38 extends full length along the portion engaged by the surface 42, this having a surface 54 which will be adjacent and opposite the upper surface of the projection or step 50, while the segment is provided with a tapered or beveled surface 56. The tapering of the segments of the pole pieces away from the air gap between the pole pieces and away from the armature air gap or gaps, provides a maximum flux density at the armature air gap, or gaps, that is the four air gaps facing the surfaces 42, 44, 46 and 48, when the actuator is in unenergized position.

The armature 28 is arranged to have a width so that it fits somewhat loosely inside the cylindrical part of the bobbin 14 and is readily movable in the slot 27 in the shaft 26, so that when the actuator is energized, the armature will automatically adjust itself in the slot with respect to the segments of the pole pieces so that the respective contact surfaces of the armature will engage and fit the respective surfaces of the pole segments.

When an electric current is passed through the copper wire of the coil 12 to energize the actuator, a magnetic flux is generated and flows through the ferro-magnetic materials provided by the outer shell 10, the end plates 16 and 18, the pole pieces 22 and 24, and the armature 28. The polarities of the pole pieces 22 and 24 are such as to provide a magneto-motive force which attracts the armature 28, thus causing the non-magnetic shaft 26 to rotate until the armature closes a magnetic circuit across the pole pieces, thereby swinging the actuating arm 34 to actuate a switch or other device.

The rotary magnetic actuator of the present invention provides means for obtaining a mechanical torque from an electromagnetic circuit whose air gaps are so arranged as to work in the most central section of the core of the electromagnet, thus delivering maximum efficiency, minimum inertia, and complete balance.

The shell of the actuator may be provided with a suitable bracket for mounting the actuator in a fixed position, or a suitable mounting may be provided for the end of the shaft 26, so that it is held in fixed position against rotation, while the casing of the actuator is rotated when current is supplied. The rotation of the casing may be transmitted by belt or other means to operate a switch or other device or devices.

I claim:

1. In a rotary electromagnetic actuator, an actuating coil having an axial opening therethrough, a pair of similar fixed pole pieces of ferro-magnetic material extending into said opening respectively from the opposite ends of the actuating coil, the inner ends of the pole pieces being spaced apart to provide an air gap therebetween in the lengthwise central section of the coil, a rotatable shaft of non-magnetic material extending axially through said coil and pole pieces, each pole piece including two similar spaced inner-end portions respectively on opposite sides of said shaft, said inner-end portions having similar parallel flat inwardly-facing engagement surfaces, and an armature of ferro-magnetic material carried by said shaft and located entirely in the coil opening between the engagement surfaces of the inner end portions of said pole pieces in overlapping relationship with respect to both pole pieces, said armature and shaft being arranged for rotation together and said armature including flat surfaces adapted to respectively and simultaneously engage the flat engagement surfaces of the inner-end portions of both pole pieces on opposite sides of said shaft when the coil is energized.

2. A rotary electromagnetic actuator as claimed in claim 1 in which the inner-end portions of each pole piece being tapered away from the air gap and its flat engagement surface, thereby providing maximum flux density at the position of the air gap.

3. In a rotary electromagnetic actuator, an actuating coil having an axial opening therethrough, a pair of similar fixed pole pieces of ferro-magnetic material extending into said opening respectively from the opposite ends of the actuating coil, the inner ends of the pole pieces being spaced apart to provide an air gap therebetween, a rotatable shaft of non-magnetic material extending axially through said coil and pole pieces, each pole piece including similar spaced inner-end portions on opposite sides of said shaft, said inner-end portions having similar flat surfaces parallel to each other and to the shaft, the flat surfaces of one pole piece being respectively in the same plane as the flat surfaces of the other pole piece, and an armature of ferro-magnetic material carried by said shaft and located entirely in the coil opening between the flat surfaces of said pole pieces in overlapping relationship with respect to both pole pieces, said armature including oppositely arranged projections extending into the air gap between the inner ends of the pole pieces for increasing the pull on the armature when the coil is energized, said armature and shaft being arranged for rotation together and said armature including surfaces adapted to respectively engage the flat surfaces of both pole pieces on opposite sides of said shaft when the coil is energized.

4. In a rotary electromagnetic actuator, an actuating coil having an axial opening therethrough, a pair of similar fixed pole pieces of ferro-magnetic material extending into said opening respectively from the opposite ends of the actuating coil, the inner ends of the pole pieces being spaced apart to provide an air gap therebetween, a rotatable shaft of non-magnetic material extending axially through said coil and pole pieces, each pole piece including similar spaced inner-end portions on opposite sides of said shaft, said inner-end portions having similar flat surfaces parallel to each other and to the shaft, the flat surfaces of one pole piece being respectively in the same plane as the flat surfaces of the other pole piece, said shaft having an elongated opening therethrough at

5

6

the position of said surfaces, and an armature of ferro-magnetic material extending through said opening and having portions projecting on opposite sides of the shaft between the flat surfaces of said pole pieces and in overlapping relationship with respect to both pole pieces, said armature being movable in said opening for automatic adjustment with respect to the pole pieces, said armature and shaft being arranged for rotation together and said armature including surfaces adapted to respectively engage the flat surfaces of both pole pieces on opposite sides of said shaft when the coil is energized.

5. In a rotary electromagnetic actuator, an annular actuating coil winding, a pair of similar fixed pole pieces of ferro-magnetic material extending axially inside the coil winding respectively from the opposite ends of the winding, the inner ends of the pole pieces extending toward each other and being spaced apart to provide an air gap therebetween in the central section longitudinally of the winding, each pole piece including a pair of similar spaced inner-end portions facing each other respectively on opposite sides of the axis of the coil winding and forming a gap therebetween, said inner-end portions having similar elongated flat engagement surfaces, the flat engagement surface of each inner end portion of one pole piece being in the same plane as the engagement surface of the corresponding end portion of the other pole piece, a rotatable armature of ferro-magnetic material located entirely within the coil winding and symmetrically with respect to the longitudinal center and axis of the coil winding, said armature extending in the gaps between the end portions of both pole pieces and in overlapping relationship symmetrically with respect to the inner-end portions of both pole pieces, and means for mounting said armature for rotation on the axis of the coil winding, said armature including elongated flap engagement surfaces adapted to respectively and simultaneously engage the elongated flap engagement surfaces of both pole pieces on opposite sides of the axis of the coil winding when the coil winding is energized.

6. A rotary electromagnetic actuator as claimed in claim 5, in which said armature includes similar opposite projecting segments intermediate its ends extending partly into the air gap between the inner ends of the pole pieces for increasing the pull on the armature when the coil is energized, said projecting segments being moved farther into the air gap after the coil is energized.

7. In a rotary electromagnetic actuator, an annular actuating coil, a pair of similar fixed pole pieces of ferro-magnetic material extending axially into the coil respectively from its opposite ends, the inner ends of the pole pieces being spaced apart at the lengthwise center of the coil to provide an air gap between the inner ends of the

pole pieces, each pole piece inside the coil including a pair of similar laterally spaced portions including the inner ends of the pole piece respectively on opposite sides of the axis of the coil, said similar laterally spaced portions having similar engagement surfaces, the engagement surfaces of the pair of spaced portions of one pole piece being respectively in line with the corresponding engagement surfaces of the pair of spaced portions of the other pole piece, an armature of ferro-magnetic material located symmetrically with respect to the longitudinal center of the coil between the pairs of spaced portions of said pole pieces and in overlapping relationship lengthwise with respect to the pairs of spaced portions of both pole pieces, and means for mounting said armature for rotation on the axis of the coil, said armature laterally overlapping each pair of spaced pole portions and including engagement surfaces adapted to respectively engage the engagement surfaces of both of the spaced portions of both pole pieces simultaneously when the coil is energized.

8. A rotary electromagnetic actuator as claimed in claim 7, in which each spaced portion of each pole piece is tapered toward its inner end to the border of its engagement surface at the air gap, whereby maximum flux density is obtained at the position of the air gap between the inner ends of the pole pieces.

9. A rotary electromagnetic actuator as claimed in claim 7, in which the engagement surface of each spaced portion extends to its inner end, and in which the cross-sectional area of each spaced portion decreases gradually toward its inner end, whereby maximum flux density is obtained at the longitudinal center of the coil.

10. A rotary electromagnetic actuator as claimed in claim 7, including ferro-magnetic material connected to the outer portion of each pole piece and extending over and covering the end of the actuating coil thereat.

11. A rotary electromagnetic actuator as claimed in claim 7, in which the engagement surface of each spaced portion extends lengthwise thereof to its inner end, and the engagement surfaces of the armature match and substantially fit the engagement surfaces of the spaced portions of the pole pieces when the coil is energized.

References Cited in the file of this patent

UNITED STATES PATENTS

1,764,658	Stoecklin	June 17, 1930
2,289,227	Walker	July 7, 1942
2,353,756	Price	July 18, 1944
2,364,656	Price	Dec. 12, 1944

FOREIGN PATENTS

265,725	Great Britain	Feb. 17, 1927
---------	---------------	---------------