

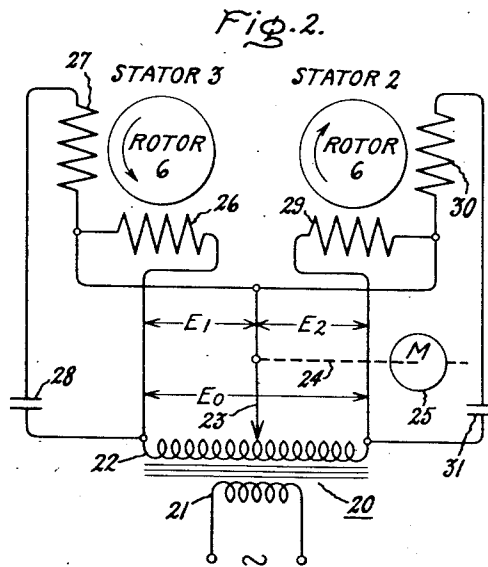
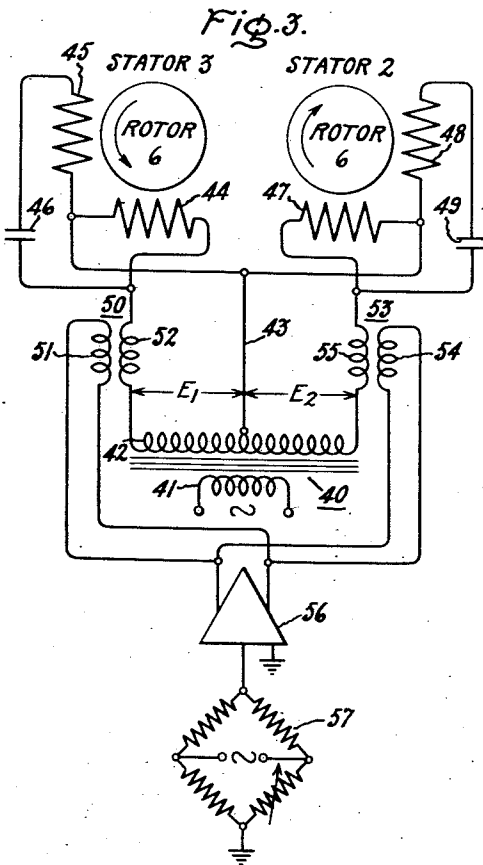
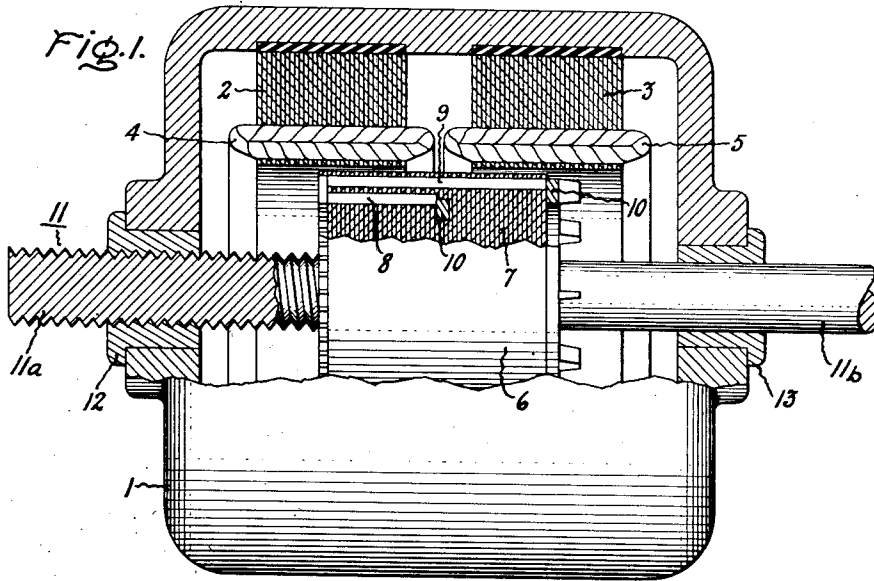
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W. A. MORGAN

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ELECTRICAL LINEAR ACTUATING ELEMENT

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Inventor:
Walter A. Morgan,
by *Norton D. Morse*
His Attorney.

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ELECTRICAL LINEAR ACTUATING ELEMENT

Walter A. Morgan, Latham, N. Y., assignor to General Electric Company, a corporation of New York

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10 Claims. (Cl. 318-48)

This invention relates to a linear electrical actuating element which can be utilized for remote positioning applications such as positioning a valve or cutting tool.

In the past, pneumatic linear actuating elements have been known and used to operate devices such as control valves. These pneumatic devices position the valves in direct relationship to the applied air pressure and permit the remote control of the valve in any position from full-open to full-closed. The inherent disadvantage of pneumatic valves is the need for long runs of tubing to carry the controlled air pressure to the valve from the control point and the consequent time lag due to the capacity of the long line and of the actuating element.

As a result, it is desirable to provide a linear actuating element which is electrically controlled. While electrically operated actuating devices were known in the prior art, there were generally unsatisfactory for many uses. Of these, solenoid operated valves are a typical example of one type of device which utilizes electrically controlled actuation. However, such solenoid operated valves are basically on-off controllers providing at best a multiplicity of discrete positions and do not permit smooth positioning over an uninterrupted range.

Another prior art approach to electrically operated actuating devices involved motorized valves which permit the setting of the opening of the valve at any desired point. However, these devices are non-linear and consequently require some form of remote valve positioning indicator in order to permit the operator to set the valve at the desired position.

It is an object of this invention, therefore, to provide a simple electrically controlled actuating element.

Another object of this invention is to provide an electrically controlled actuating element which is linear in character.

Yet another object of this invention is to provide an electrically controlled linear actuating element which may be positioned over a continuous and uninterrupted range of positions.

Briefly speaking, the apparatus embodying the instant invention contemplates applying two opposing magnetic fields to a common rotor member. The opposing magnetic fields exert opposing driving torques on the common rotor with the stronger magnetic field determining the final direction of rotation. Coupled to the rotor is a motion translating means, such as a threaded shaft portion, which translates the rotational movement of the rotor into a linear axial displacement thereof. The net result of the axial displacement of the rotor is that the rotor finds an equilibrium position between the opposing influences of the two magnetic fields. The magnetic fields may be produced by two stators and their associated winding. By varying the voltages applied to the windings, either manually or in response to some conditions, the magnetic fields are varied and a linear displacement of the rotor is achieved. Thus, a continuous and uninterrupted range of settings may be obtained by varying the relative field voltages.

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The novel features which are believed to be characteristic of this invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings, in which

Fig. 1 shows a sectional view of the linear actuating mechanism of the invention;

Fig. 2 is a diagrammatic showing of the electrical circuit for controlling the field voltage of the actuating element of Fig. 1; and

Fig. 3 is an alternative embodiment of the field winding control circuit of Fig. 2.

Referring now to Fig. 1, there is shown an electrically controlled linear actuating element which includes means to produce two opposing, torque producing, magnetic fields which act on a common rotatable member to impart rotation thereto in a direction dependent on the sense of the resultant of the opposing magnetic fields. Mounted in end-to-end relation within a housing 1 are a pair of electrically independent, split phase, squirrel cage type stators 2 and 3, each of which is constructed of a multiplicity of slotted laminations of high magnetic permeability. Mounted within the stator 2 is a stator field winding 4 which produces in conjunction with the stator a torque producing magnetic field. Similarly, the stator 3 has a stator field winding 5 mounted therein which produces a magnetic field having a torque producing effect opposite to that of stator 2.

Extending through the stators 2 and 3 and subject to the effect of both their magnetic fields is a squirrel cage rotor 6, the main portion of which is constructed of slotted laminations 7 of high magnetic permeability. Positioned within the slotted portions of the rotor 6 are a number of metallic bars 8 and 9 which may be formed of copper, brass, or aluminum. The rotor bars 8 and 9 are connected by means of end rings 10 to form a closed circuit which constitutes, as is well known in the art, a rotor winding. The stator field windings 4 and 5 are so connected, as can be most easily seen with reference to Figs. 2 and 3 which will be explained in greater detail later, that in conjunction with the rotor, the device operates at a split phase capacitor start-capacitor run motor. The stators 2 and 3 and their respective windings produce opposing magnetic fields which exert opposing driving torques on the rotor 6 through motor action. The stronger of these two magnetic fields determines the ultimate direction of rotation of the rotor 6 and controls the direction of translation.

The rotor 6 is affixed to a shaft 11 to translate its rotational movement into a linear axial displacement until an equilibrium position between the opposing influences of the stators 2 and 3 is reached. To this end, the shaft 11, which rotates with the rotor, has a threaded portion 11a and an unthreaded portion 11b. The threaded portion 11a of the shaft passes through a nut 12 positioned on the end of the housing 1 while the unthreaded shaft portion 11b passes through a sleeve bearing 13 at the other end of the housing 1. The effect of the threaded shaft portion 11a and the nut 12 is that any rotation of the rotor 6 imparts a motion of translation which axially displaces the rotor in a direction depending on the sense of the rotation.

The phasing of the voltages applied to the respective field windings of each stator and the direction of threading on the rotor shaft are set up in such a manner that the torque exerted on the rotor by either stator diminishes if the rotor turns in the direction of the torque and increases if it turns in the opposite direction. That is, if, for example, the voltage applied to the field winding 5 of the stator 3 is the larger and is such as to produce

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a counterclockwise rotation of rotor 6, observing the rotor from the threaded shaft end the axial translation produced by the threaded shaft portion 11a causes the rotor to move to the left and out of the influence of the torque producing magnetic field of stator 3. In a similar fashion, if the torque producing magnetic field of stator 2 is the larger and produces a clockwise rotation, again observing the rotor from the threaded shaft end of the rotor, the axial translation of the rotor is to the right and out of the influence of the magnetic field of stator 2. That is, as linear axial translation takes place, the relative amount of the rotor within the stronger field is decreased while the relative amount within the weaker field is increased. In this fashion, the rotor 6 can be driven toward the left or right, depending upon which stator develops the greatest torque in the rotor, until an equilibrium position between the effects of the two fields and the relative amounts of the rotor within each is reached.

Referring now to Fig. 2, the electrical circuit means for supplying and varying the voltage to the individual field windings of the stators 2 and 3 is shown. An iron core transformer 20 is illustrated as connected between a source of alternating voltage, not shown, and the field windings of the stators 2 and 3 to provide a source of energy therefor. The primary winding 21 of the transformer 20 is connected to a suitable source of alternating voltage while the secondary winding 22 is connected, as will be presently described, to the field windings of the stators 2 and 3. A movable tap 23 is positioned on the secondary winding 22 and is utilized to vary the relative magnitude of the voltages applied to the field windings of the stators 2 and 3. The field winding of stator 3 consists of a main stator winding 26 connected between one terminal of the secondary windings 22 and the movable tap 23, and starting winding 27 in series with a phase shifting capacitor 28 connected between the movable center tap 23 and the same end of the winding 22. This arrangement is old and well known in the art as a capacitor motor or split phase capacitor start-capacitor run motor. In a similar fashion, the field winding of stator 2 includes a main winding 29 connected between the movable tap 23 and the other terminal of the secondary winding 22, and starting winding 20 and phase shifting capacitor 31 connected between said movable tap 23 and the other terminal of the winding 22.

It can be seen that the voltages E_1 and E_2 applied to the respective field windings are of opposite phase and exert opposing torques on the rotor. The relative magnitudes of these voltages E_1 and E_2 determines which of the stators develops the greater driving torque and the ultimate direction of rotation. Consequently, by adjusting the position of the center tap 23 along the winding 22, the relative magnitudes of the voltages E_1 and E_2 are adjusted. To this end, the movable tap 23 may be connected to a driving means such as a motor 25 by means of a shaft 24 to provide a means for varying these voltages. The motor 25 may be actuated in response to a condition sensing device, a servo system, or any other suitable control condition. Of course, it is entirely feasible and within the scope of this invention to control the center tap 23 manually in order to actuate the device.

In considering the operation of the instant invention and in order to determine the full scope of the invention, it is helpful to derive the general equation of operation of the device. E_1 is the voltage applied to stator 3 tending to cause counterclockwise rotation, assuming the rotor is observed from the threaded shaft end, and E_2 is the voltage applied to stator 2 tending to cause clockwise rotation. The clockwise torque T_c exerted on the rotor by the stator 2 at zero speed is:

$$T_c = CE_2(E_2b - E_1a)b \quad (1)$$

and the counterclockwise torque T_{cc} produced by stator 3 in the rotor is:

$$T_{cc} = CE_1(E_2b - E_1a)a \quad (2)$$

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where a and b are the amounts of the rotor in stators 3 and 2 respectively and C is a constant. If a thrust L is applied to the end of the rotor shaft and negligible friction between the screw and nut is assumed, then:

$$\frac{L}{P} = CE_2(E_2b - E_1a)b - CE_1(E_2b - E_1a)a \quad (3)$$

or

$$\left(\frac{L}{CP}\right)^{1/2} = E_2b - E_1a \quad (4)$$

where P equals the number of threads per inch of the nut. For a given control condition, let

$$X = \frac{E_1}{E_0}, \quad 1 - X = \frac{E_2}{E_0}, \quad \text{and } a = s - b$$

Equation 4 may now be rewritten as:

$$\left(\frac{L}{CP}\right)^{1/2} = (1 - X)E_0b - XE_0a \quad (5)$$

$$\frac{\left(\frac{L}{CP}\right)^{1/2}}{E_0} = (1 - X)b - Xa = (1 - X)b - X(s - b) \quad (6)$$

$$\frac{\left(\frac{L}{CP}\right)^{1/2}}{E_0} = b - Xb - Xs + Xb = b - Xs \quad (7)$$

$$b = \frac{\left(\frac{L}{CP}\right)^{1/2}}{E_0} + Xs \quad (8)$$

Equation 8 is the general equation of operation of the device and indicates that for a constant thrust load and supply voltage, the axial position of the rotor is linearly related to the input parameter X .

Referring now to Fig. 3, there is disclosed an alternative manner of varying the relative magnitudes of the voltages applied to the field windings of the respective stators 2 and 3. That is, rather than moving an adjustable tap in order to vary the relative magnitudes of the voltages, it is possible to produce the same result by differentially adding a control voltage to the field voltages E_1 and E_2 . To this end, an iron core transformer 40 having a primary winding 41 and a secondary winding 42 is connected between a source of suitable alternating voltage and the field windings of the stators 2 and 3. A fixed center tap 43 on the secondary winding 42 divides the voltage thereacross into two components E_1 and E_2 of equal magnitude. Stator 3 has a main winding 44 connected between one terminal of the secondary transformer winding 42 and the fixed center tap 43. A start winding 45 in series with a phase shifting capacitor 46 is also connected between the center tap 43 and the same end of the transformer secondary winding. Stator 2 similarly comprises a main winding 47, start winding 48, and a phase shifting capacitor 49 connected in a similar manner between the center tap 43 and the other terminal of the secondary winding 42.

A condition responsive A. C. bridge 57 energized from the same source of alternating voltage as the transformer 40 is utilized to provide a control signal which will be differentially added to the field voltages. The output of bridge 57, which varies in magnitude and sense in response to a control condition which varies one of the bridge elements, is connected to the input of an amplifier 56, the output of which is connected to a pair of transformers 50 and 53. The primary winding 51 of the transformer 50 is connected to the output of the A. C. amplifier 56 while the secondary winding 52 is connected in series with the main and start windings of the stator 3. In a similar fashion, the primary winding 54 of the transformer 53 is connected to the output of the amplifier 56 while the secondary winding 55 is connected in series with the main and start windings of the stator 2. The winding sense of the transformers 50 and 53 are such

that for a given output signal from the bridge 57, the output of the amplifier 56 will be additive with respect to the voltage of one of the field windings and subtractive from the other. In this fashion, the voltage applied to the field windings of one of the stators will be larger than that applied to the other, and one of the stators will thus develop a greater torque in the rotor tending to drive it in one direction or the other. As the sense of the output signal from the bridge 57 changes, one or the other of the stators will exert the greater torque and control the direction of rotation and, in turn, the direction of axial displacement.

In the control circuit illustrated in Fig. 3, a fixed center tap 43 is disclosed which divides the voltage across secondary winding into two components E_1 and E_2 of equal magnitude. It is obvious that the center tap 43 may be movable in order to provide a number of reference positions of the rotor about which the rotor may move in response to control signals from the bridge 57. That is, the equilibrium position which the rotor assumes in the absence of control signals from the bridge 57 may be adjusted by moving the tap 43 and thus movement of the rotor in response to the bridge control signals, may be made to vary around a number of such reference positions.

Although the apparatus embodying the instant invention has been shown as utilizing single phase motor principles, it will, of course, be obvious to the man skilled in the art that the invention encompasses an apparatus in which multiphase motor principles are utilized.

While a particular embodiment of this invention has been shown, it will, of course, be understood that the invention is not limited thereto since many modifications both in the circuit arrangement and in the instrumentalities employed may be made. It is contemplated by the appended claims to cover any such modifications as fall within the true spirit and scope of this invention.

What I claim as new and desire to obtain by Letters Patent of the United States is:

1. In an electrical linear actuating device the combination comprising, means to produce at least two opposing torque producing magnetic fields, means positioned within said magnetic fields and rotatable thereby in a direction dependent on the relative strength of said opposing magnetic fields, means to translate rotational movement of said rotatable means into linear axial displacement thereof until an equilibrium position relative to said opposing magnetic fields is attained.

2. In an electrical linear actuating device, the combination comprising, means to produce at least two opposing torque producing magnetic fields, means positioned within said magnetic fields and rotatable thereby in a direction dependent on the relative strength of said opposing magnetic fields, means to vary the magnitude of said magnetic fields, means to translate rotational movement of said rotatable means into linear axial displacement thereof until an equilibrium position as between the opposing magnetic fields is attained.

3. In an electrical linear actuating device the combination comprising, means to produce a first torque producing magnetic field, means to produce a second torque producing magnetic field opposed to said first field, means common to said first and second magnetic fields and rotatable thereby in a direction determined by the stronger of said fields, means to translate rotational movement of said rotatable means into linear axial displacement thereof until an equilibrium position relative to said magnetic field is attained.

4. In an electrical linear actuating device, the combination comprising, a first stator means for establishing a first magnetic field, a second stator means for establishing a second opposing magnetic field, a common rotor member extending through said stator members adapted to be rotated in a direction determined by the stronger of said first and second magnetic fields, motion translat-

ing means including threaded means associated with said rotor means to translate rotation into axial displacement until said rotor achieves an equilibrium position.

5. In an electrical linear actuating element the combination comprising, a first stator for producing a first magnetic field, a second stator for producing a second opposing magnetic field, a common rotor member adapted to be acted upon by said first and second magnetic fields and rotated in a direction determined by the stronger of said magnetic fields, shaft means connected to said rotor having a threaded portion on one end thereof, a nut adapted to receive said threaded portion to translate rotation of said rotor into axial displacement thereof until an equilibrium position relative to said opposing magnetic fields is attained.

6. In an electrical linear actuating device, the combination comprising a first stator for producing a first magnetic field, a second stator for producing an opposing magnetic field, a common rotor member adapted to be acted upon by said first and second magnetic fields and rotated in a direction determined by the stronger of said magnetic fields, motion translation means including threaded shaft means connected to said rotor to translate rotation into axial displacement until an equilibrium position relative to said opposing magnetic fields is attained, means to vary said first and second magnetic fields whereby the axial position of said rotor may be varied.

7. In an electrical linear actuating device the combination comprising, a first stator including field windings for producing a first magnetic field, a second stator including field windings for producing an opposing magnetic field, a common rotor member adapted to be acted upon by said first and second magnetic fields and rotated in a direction determined by the stronger of said magnetic fields, motion translating means including threaded shaft means to translate rotation into axial displacement until an equilibrium position relative to said opposing magnetic fields is attained, variable voltage means connected to said field windings to produce said magnetic fields.

8. In an electrical linear actuating device the combination comprising, a first stator including field windings for producing a first magnetic field, a second stator including field windings for producing an opposing magnetic field, a common rotor member adapted to be acted upon by said first and second magnetic fields and rotated in a direction determined by the stronger of said magnetic fields, motion translating means including threaded shaft means to translate rotation into axial displacement until an equilibrium position relative to said opposing magnetic fields is attained, voltage means so connected to said field windings to provide oppositely phased stator field winding voltages, means to vary the relative magnitude of said stator field winding voltages whereby the axial position of said rotor is varied.

9. In an electrical linear actuating device the combination comprising, a first stator including field windings for producing a first magnetic field, a second stator including field windings for producing an opposing magnetic field, a common rotor member adapted to be acted upon by first said and second magnetic fields and rotated in a direction determined by the stronger of said magnetic fields, motion translating means including threaded shaft means to translate rotation into axial displacement until an equilibrium position relative to said opposing magnetic fields is attained, a voltage source having the field windings of said first stator connected across one portion thereof, and the field winding of said second stator connected across the remaining portion, means to vary the portions of said voltage supply applied to the respective field windings whereby the axial position of said rotor is varied.

10. In an electrical linear actuating device the combination comprising, a first stator including field windings for producing a first magnetic field, a second stator including field windings for producing an opposing magnetic field, a common rotor member adapted to be acted

upon by said first and second magnetic fields and rotated in a direction determined by the stronger of said magnetic fields, motion translating means including threaded shaft means to translate rotation into axial displacement until an equilibrium position relative to said opposing magnetic fields is attained, a voltage source so connected to said field windings to provide oppositely phased stator field

winding voltages, means to apply a control voltage differentially to said field windings to vary the relative magnitudes of said stator field winding voltages whereby the axial position of said rotor is varied.

No references cited.