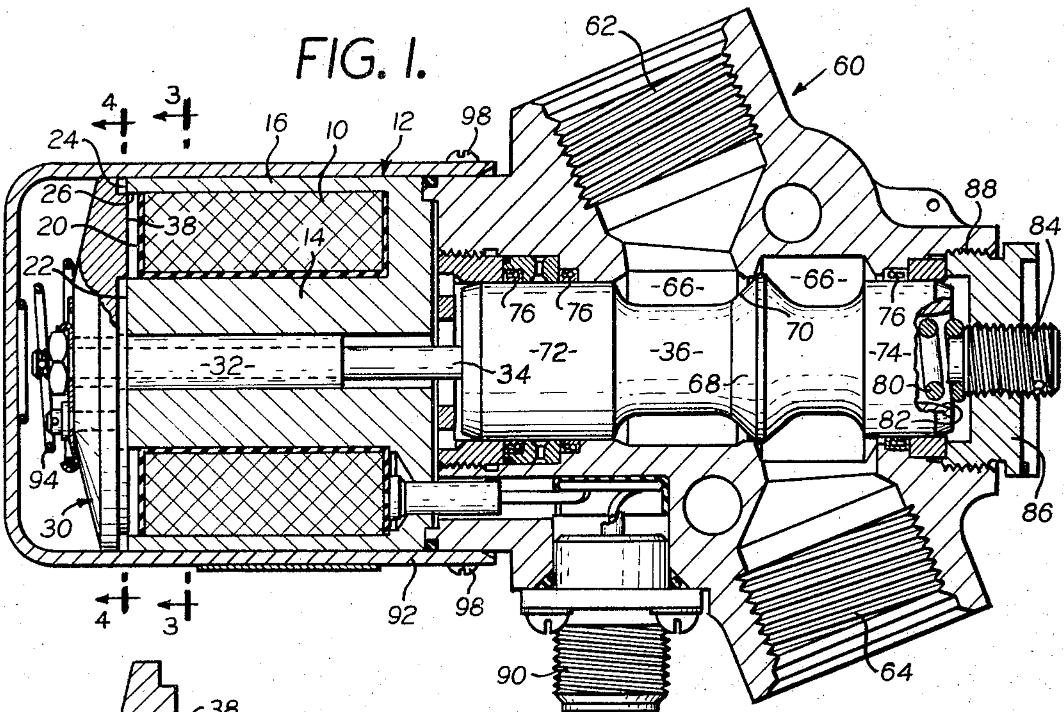
Feb. 13, 1968 D. L. WELLS 3,368,791

VALVE WITH MAGNETIC ACTUATOR

Filed July 14, 1964

FIG. 1.



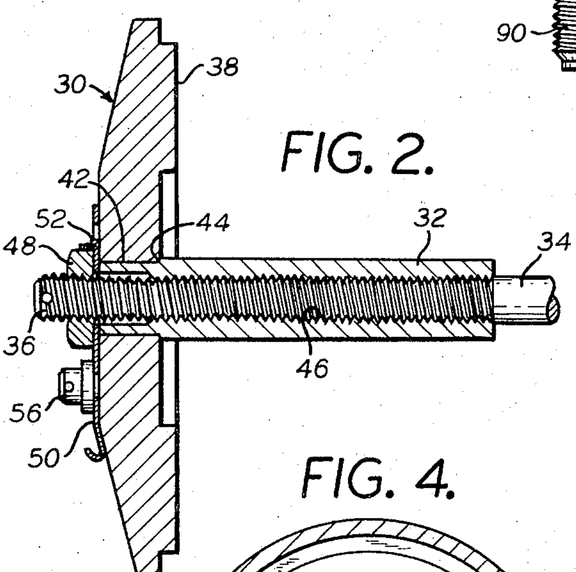


FIG. 2.

FIG. 3.

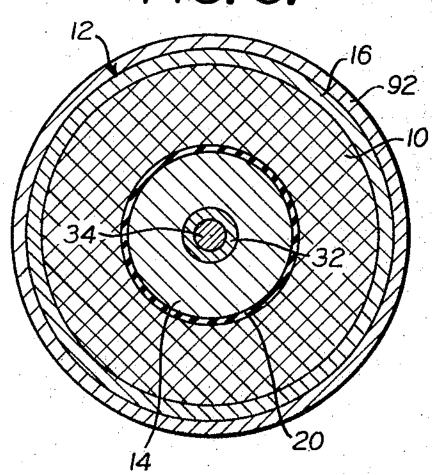
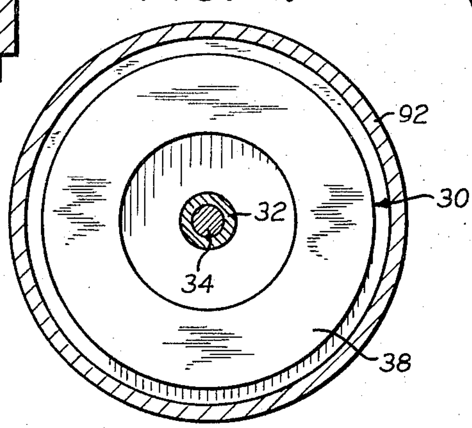


FIG. 4.



INVENTOR

David Leon Wells

BY Emery, Whittemore, Sandoe & Graham

ATTORNEYS.

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VALVE WITH MAGNETIC ACTUATOR

David Leon Wells, Huntington Beach, Calif., assignor to Marotta Valve Corporation, Boonton, N.J., a corporation of New Jersey

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This invention relates to electro-magnetic valve actuators and to combinations of such actuators and valve assemblies.

It is an object of the invention to provide an improved valve actuator having an armature that is attracted by a coil and that transmits its motion to a valve element, either to open or to close the valve.

The invention is more particularly concerned with valve assemblies in which the valve actuator has an armature that extends across an end face of an iron frame having a coil for producing a magnetic flux, and in which the slope of the force curve changes very rapidly as the armature approaches the coil and magnetized frame. Such a force curve is ideal for obtaining a "snap action" of the valve element; and for moving a valve element against the force of a high-rate spring which produces snap action operation of the valve element in the opposite direction as the magnetism of the coil and frame decrease when the coil is de-energized.

The invention provides a valve actuator with an armature that obtains greater pull for starting the movement of a valve element when a gap between the armature and the coil and/or magnetized frame is at a maximum at the beginning of a stroke, while retaining a rising force curve at the other end of the stroke.

The invention provides a raised or stepped portion of the armature which moves into a recess in the confronting composite face of the coil and frame to obtain a flatter force curve when the gap is large but without destroying the rise in force at the end of the stroke where such a rise is useful for compressing a spring that opposes the movement of the armature.

In addition to an increase in force for starting the operation of a valve element, the invention can also be used, where no additional force is required, to operate the actuator at lower voltage and current than was previously necessary.

Other objects, features and advantages of the invention will appear or be pointed out as the description proceeds.

In the drawing, forming a part hereof, in which like reference characters indicate corresponding parts in all the views:

FIGURE 1 is a sectional view of a valve assembly equipped with an electro-magnetic actuator made in accordance with this invention;

FIGURE 2 is a detail sectional view showing the armature and its connection to the sleeve by which the armature can be adjusted with respect to the connecting means through which it actuates a valve element; and

FIGURES 3 and 4 are sectional views taken on the lines 3—3 and 4—4, respectively, of FIGURE 1.

The electro-magnetic actuator shown in FIGURE 1 includes a coil of wire **10**, the coil being of annular cross section. The coil is associated with a fixed iron frame **12** which includes a core **14** that fills the space within the annular coil **10**, and a cover **16** which extends around the outside of the coil **10**. In the construction illustrated the core **14** and the cover **16** are of one-piece construction, but composite constructions can be used. In describing the frame **12** as "iron," this term is used in a broad sense to indicate ferrous metal or metal alloys which will be magnetized by the flow of electric current in the coil **10**. Any metal not containing iron but which is similarly magnetized under the circumstances is to be considered a mechanical equivalent.

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The coil **10** has an end face **20**; and the core **14** and cover **16** have end faces **22** and **24**, respectively. In the preferred construction, the end faces **22** and **24** are annular surfaces in a common plane.

The end face **20** of the coil **10** is set back from the plane of the end faces **22** and **24** so that the composite end face of the combined coil **10** and frame **12** has an annular recess **26** over the end face of the coil **10**.

An armature **30** extends across the end faces **20**, **22** and **24**; and this armature is connected to a sleeve **32** which threads on a shaft **34** by which the armature is connected with a valve element **36**.

The front face of the armature **30** has a raised portion **38** corresponding to the recess **26** in the composite face of the coil **10** and frame **12** which confronts the armature. This raised portion **38** of the armature is shown with a cross section which fits into the recess **26** and the height of the raised portion **38**, with respect to the remaining area of the front face of the armature, is shown substantially equal to the depth of the recess **26**. This "depth" is the distance by which the core **14** and cover **16** extend beyond the end face **20** of the coil **10**. The recess **26** may be of greater depth, if desired.

When the armature is at the left-hand end of its stroke, the plane of the annular front face of the raised portion **38** preferably coincides with the plane of the end faces **22** and **24** of the core **14** and cover **16**, respectively. When the armature **30** is at the right-hand end of its stroke, the front face of the armature beyond the raised portion **38** is in contact, or substantial contact, with the end faces **22** and **24**.

In actual practice, it is advantageous to avoid actual contact unless the armature of the faces **22** and **24** have non-magnetic material on them to prevent such contact and thus avoid having the force, which holds are armature against the frame **12**, vary along a line that becomes asymptotic.

The force of attraction of the armature **30** toward the coil **10** and frame **12** varies somewhat with changes in the height of the raised portion **38** for any particular gap between the armature **30** and the coil **10** and frame **12**. As compared with the armatures of the prior art, which did not have the raised portion **38**, the force attracting the armature to the coil and frame is much higher for any particular gap at the beginning of the stroke; that is, when the armature is at the left-hand end of its travel. As the armature approaches the coil **10** and frame **12**, however, the difference between the force curve of a conventional armature and the stepped armature of this invention becomes less and while the raised portion **38** decreases the slope of the curve at the beginning of the stroke, it does not prevent the sharp rise which produces the desirable snap action obtained with conventional armatures for actuators of the type on which this invention is an improvement.

FIGURE 2 shows the way in which the armature **30** is connected with the shaft **34**. The sleeve **32** has an end portion **42** of slightly reduced outside diameter leaving a shoulder **44** at a distance from the end of the sleeve substantially equal to the axial thickness of the armature **30**. This reduced-diameter portion **42** of the sleeve **32** fits into a center opening through the armature **30** with a press fit; and the shoulder **44** limits the extent to which the sleeve **32** can be inserted into the armature. Threads **46** on the inside of the sleeve **32** screw over corresponding threads on the shaft **34** so that the armature **30** and sleeve **32** can be adjusted axially along the shaft by rotating them.

When assembled in the intended manner, the shaft **34** extends beyond the end of the sleeve **32** and there is a nut **48** screwed over the threads of the shaft **34** in position to prevent any accidental movement of the armature **30** axially on the sleeve **32**. A lock washer **50** fits over the shaft **34** between the nut **48** and the armature **30**. One end of the washer **50** is bent up at a tab **52** to prevent rotation of the nut **48** and the washer **50** itself is prevented from rotating by a screw **56** extending through an offset portion of the washer **50** and threaded into the armature.

From this description of the connection of the armature **30** with the shaft **34** it will be apparent that the armature can be shifted axially with respect to the shaft **34** so as to change the position of the armature corresponding to any given position of the valve element **36** at the other end of the shaft **34**.

The assembly shown in FIGURE 1 also includes a valve housing **60** having ports **62** and **64** with appropriate threads for connecting with tubing or piping with which the valve assembly is intended to be used. Within the valve housing **60** there is a valve chamber **66**, and the valve element **36** is reciprocated in this valve chamber **66** and has a tapered surface **68** which contacts with a circular seat **70** to close the valve and prevent flow of fluid between the ports **62** and **64**.

The valve element **36** has end portions **72** and **74** which fit into appropriate cylindrical surfaces of the valve housing to provide a pressure-balanced valve. There are sealing means **76** around the counter-balancing end portions **72** and **74** and these sealing means prevent escape of fluid from the valve chamber **66**.

At the right-hand end of the housing **60**, as viewed in FIGURE 1, there is a spring **80** which urges the valve element **36** into closed position, that is, into contact with the seat **70**. The spring **80** is preferably a high-rate spring so as to obtain snap-action closing of the valve, and the spring **80** extends into a recess **82** in the end of the valve element **36**. In order to adjust the compression of the spring **80**, a plug **84** threads through an end fitting **86** and fits into the end coil of the spring **80**. The fitting **86** is connected to the valve housing **60** by threads **88** and this fitting clamps the sealing means **76** against a shoulder formed by a counterbore in the end of the valve housing.

Power is supplied to the coil **10** by wires which connect with the coil through an electrical socket **90** attached to one side of the valve housing **60**. There is an outer cover **92** which extends over the iron frame **12** and beyond the iron frame to provide a protecting housing for the armature **30** and its connected parts. A light spring **94** is compressed between the end of the outer cover **92** and the armature **30**. This light spring **94**, which acts against the force of the much stronger spring **90**, is for the purpose of preventing vibration of the armature. The outer cover **92** fits over an end portion of the valve housing **60** and is connected to it by fastening means such as screws **98**.

The preferred embodiment of the invention has been illustrated and described, but changes and modifications can be made and some features can be used in different combinations without departing from the invention as defined in the claims.

What is claimed is:

1. An electro-magnetic actuator for a valve including a coil, a fixed iron frame adjacent to the coil and which is magnetized by electric current flowing in the coil, said frame including a cover of annular section surrounding the outside of the coil and an axial core surrounded by the coil, an armature extending across an end face of the coil and the frame, the end faces of the coil and the frame being in different planes so that they present a composite face confronting the armature but with the coil part of the area of the confronting face recessed with respect to the rest of the face, the armature having a front face opposite said composite confronting face of the coil and frame with the surface of the armature raised where said confronting face is recessed and over an area that extends into the recess as the armature approaches the end faces of the coil and frame, the surface areas of the armature that confront the cover and the core being at substantially the same distances from the cover and the core whereby the armature is subject to maximum density of flux from both said cover and core, a guide bearing on which the armature reciprocates toward and from the coil and frame, and means for connecting the armature with an element that is to be actuated thereby.

2. The electro-magnetic valve actuator described in claim **1** characterized by the core having an opening that constitutes the guide bearing, and a shaft extending through the opening and constituting the means for connecting the armature with a valve element.

3. The electro-magnetic valve actuator described in claim **1** characterized by the raised surface of the armature being of annular cross section and fitting into the annular recess.

4. The electro-magnetic valve actuator described in claim **1** characterized by a valve housing to which the frame is connected, a valve chamber in the housing, a valve element in the chamber and to which the armature is operably connected by said means for connecting the armature with the valve element.

5. The electro-magnetic valve actuator described in claim **4** characterized by inlet and outlet ports for the valve chamber, a seat with which the valve element contacts to close communication between the inlet and outlet ports, the valve actuator being in position to move the valve element one way with respect to the seat, high rate spring means for moving the valve element the other way with respect to said seat, and means for adjusting the tension of the spring.

6. The electro-magnetic valve actuator described in claim **5** characterized by the armature being secured to a sleeve that slides in said guide bearing, and the connection between the valve element and the armature including a shaft with a threaded portion that threads into a sleeve, said threaded portion extending beyond the end of the sleeve and beyond the armature, a nut on the extending portion of the shaft for locking the sleeve in any adjusted position to which it may be shifted along the threads that connect it with the shaft to regulate the position of the armature corresponding to the closed position of the valve, and releasable means for preventing rotation of said nut.

7. The electro-magnetic valve actuator described in claim **5** characterized by the high-rate spring urging the valve element into closed position, the electro-magnetic valve actuator, when energized, moving the valve element into open position, the end face of the core and cover being in substantially the same plane as the area of the armature that confronts the end face of the coil when the valve element is closed against its seat, the armature being of a shape and size to cover the entire area of the combined end faces of the core, coil and cover.

8. The electro-magnetic valve actuator described in claim **7** characterized by the valve element having portions connected through and movable in bearings in the valve housing, and in position and of such size as to pressure-balance the valve element, sealing means around portions of the valve element for preventing escape of fluid under pressure from the valve chamber, a second housing over the cover and armature, and a light spring at the armature end of the shaft and compressed between the second cover and armature and acting against the force of the high-rate spring.

9. An electro-magnetic actuator for a valve including a coil, a fixed iron frame adjacent to the coil and which is magnetized by electric current flowing in the coil, said frame including a cover of annular section surrounding the outside of the coil and an axial core surrounded by the coil, an armature extending across an end face of the coil and the frame, the end faces of the coil and the frame being in different planes so that they present a composite face confronting the armature but with part of the area of the confronting face recessed with respect to the rest of the face, the armature having a front face opposite said composite confronting face of the coil and frame with the surface of the armature raised where said confronting face is recessed and over an area that extends into the recess as the armature approaches the end faces of the coil and frame, the surface areas of the armature that confront the cover and the core being at substantially the same distances from the cover and the core whereby the armature is subject to maximum density of flux from both said cover and core, a guide bearing on which the armature reciprocates toward and from the coil and frame, and means for connecting the armature with an element that is to be actuated thereby, and characterized by means limiting the stroke of the armature to a distance substantially equal to the height of the raised portion of the armature with respect to the rest of the surface of the front face of the armature.

10. An electro-magnetic actuator for a valve including a coil, a fixed iron frame adjacent to the coil and which is magnetized by electric current flowing in the coil, said frame including a cover of annular section surrounding the outside of the coil and an axial core surrounded by the coil, an armature extending across an end face of the coil and the frame, the end faces of the coil and the frame being in different planes so that they present a composite face confronting the armature but with part of the area of the confronting face recessed with respect to the rest of the face, the armature having a front face opposite said composite confronting face of the coil and frame with the surface of the armature raised where said confronting face is recessed and over an area that extends into the recess as the armature approaches the end faces of the coil and frame, the surface areas of the armature that confront the cover and the core being at substantially the same distances from the cover and the core whereby the armature is subject to maximum density of flux from both said cover and core, a guide bearing on which the armature reciprocates toward and from the coil and frame, and means for connecting the armature with an element that is to be actuated thereby, and characterized by the raised surface of the armature being of annular cross section and fitting into the annular recess, and further characterized by the end faces of the core and cover being in substantially the same plane, and means for limiting the stroke of the armature including an element that stops the movement of the armature away from the coil and frame at a position in which the raised surface of the armature is in substantially the same plane as the end faces of the core and cover.

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M. CARY NELSON, *Primary Examiner.*

ROBERT C. MILLER, *Assistant Examiner.*