

July 19, 1955

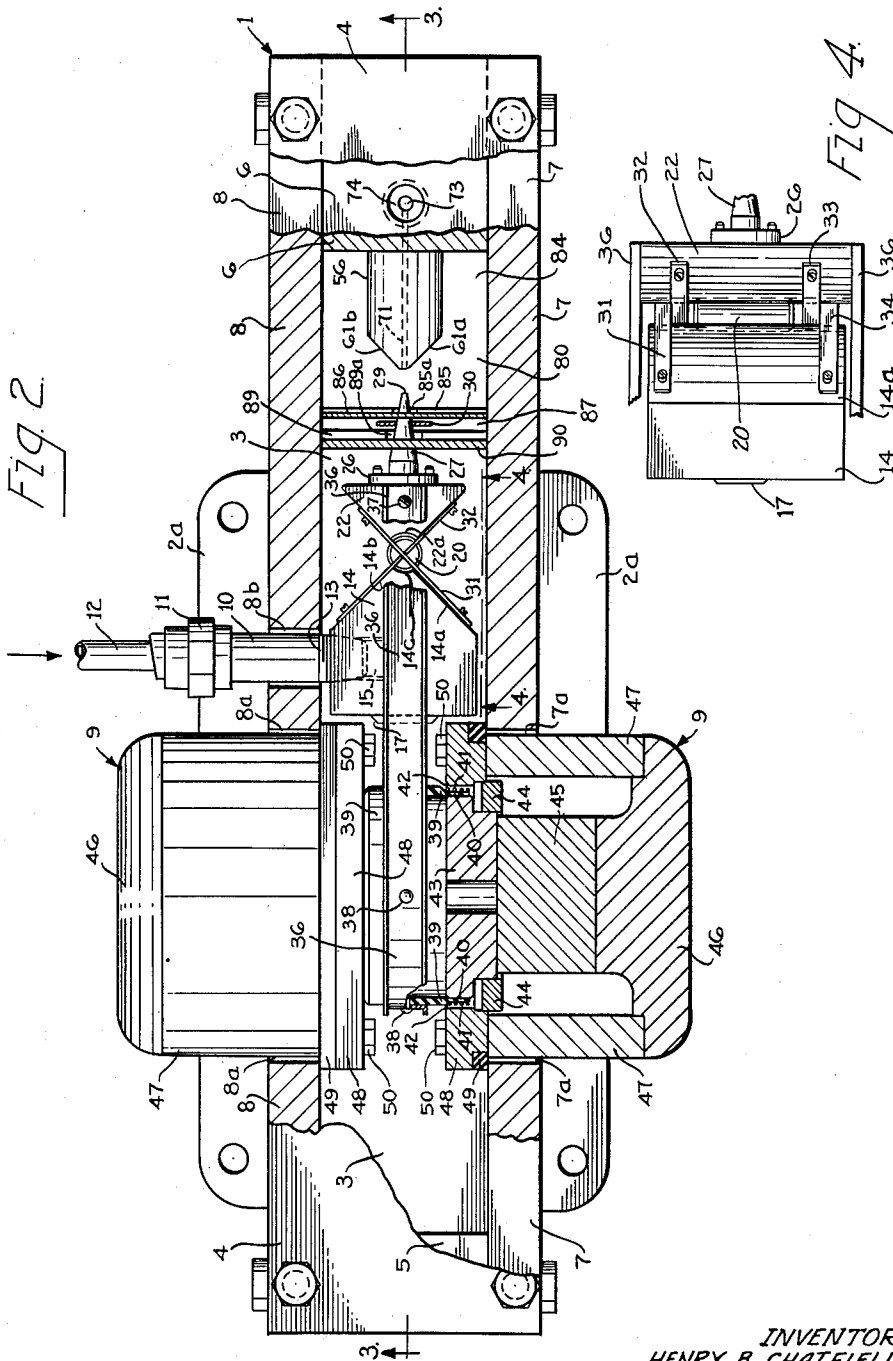
H. B. CHATFIELD

2,713,348

CONTROL MECHANISM EMPLOYING THE JET-PIPE PRINCIPLE

Filed Jan. 9, 1953

3 Sheets-Sheet 2



INVENTOR.
 HENRY B. CHATFIELD
 BY *Rosworth, Seaverson,
 Norstrom & Williams*
 ATTORNEYS.

July 19, 1955

H. B. CHATFIELD

2,713,348

CONTROL MECHANISM EMPLOYING THE JET-PIPE PRINCIPLE

Filed Jan. 9, 1953

3 Sheets-Sheet 3

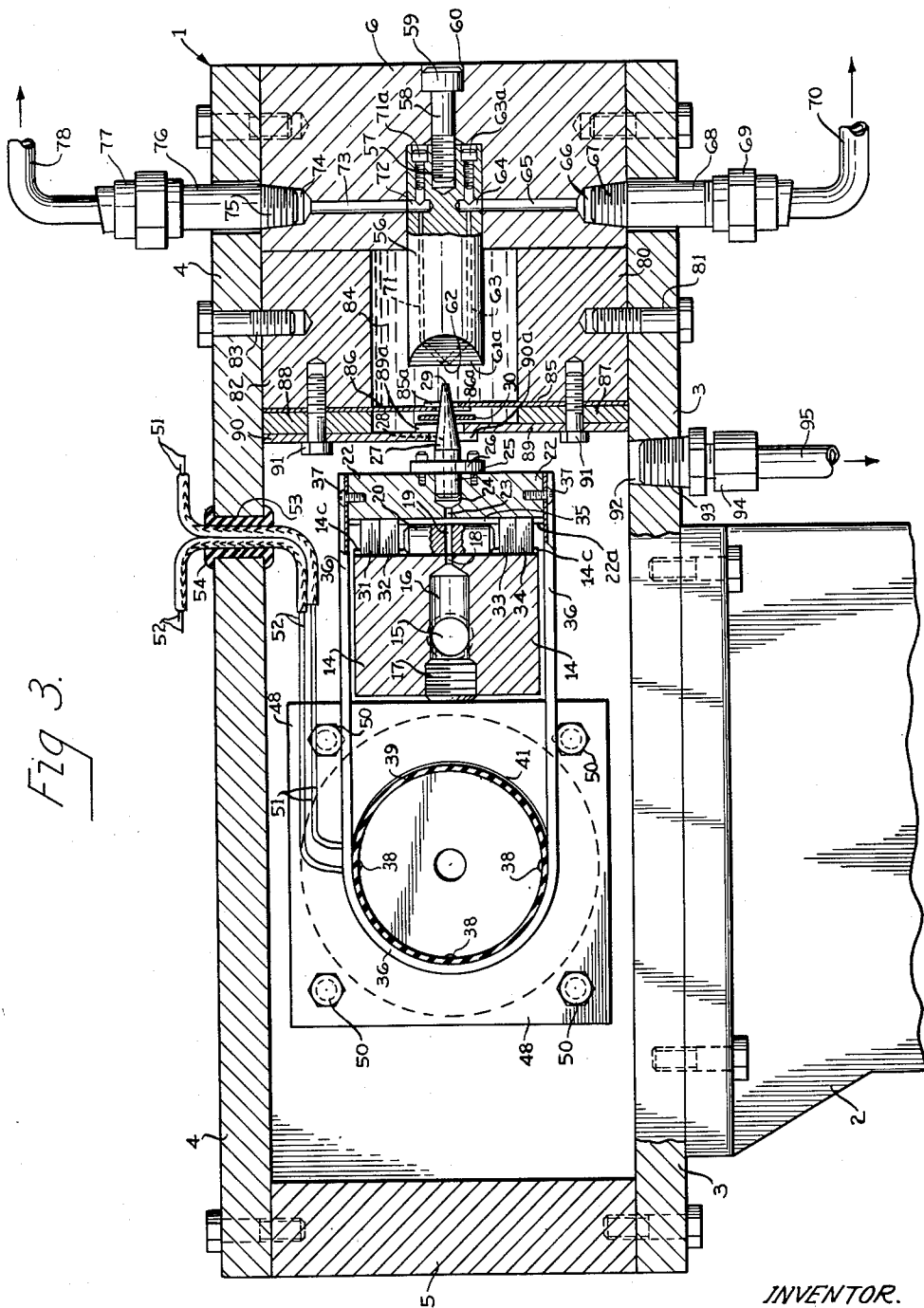


Fig. 3.

INVENTOR.
HENRY B. CHATFIELD
BY *Rosworth, Sessions,
Harrison & Williams*
ATTORNEYS.

1

2,713,348

CONTROL MECHANISM EMPLOYING THE JET-PIPE PRINCIPLE

Henry B. Chatfield, Kinsman, Ohio

Application January 9, 1953, Serial No. 339,561

10 Claims. (Cl. 137—83)

This invention relates to a control mechanism and, more particularly, to a control mechanism for translating an electrical impulse of small magnitude into a force of large magnitude.

Heretofore control mechanisms have been available which have been capable of translating electrical impulses into mechanical forces, but such have not in general been sensitive enough to permit of their employment where a response upwards of some hundreds of cycles a minute is required. In the main, those prior art devices that have been used for translating electrical impulses into mechanical forces have availed themselves of solenoids, torque motors and similar power components characterized by elements such as plungers, shafts and the like that of necessity have had a considerable mass. In part because of the mass factor, control mechanisms making use of power components of this type, although adapted to uses where a low level of frequency response is satisfactory, are too sluggish for use where a high frequency response is a requirement.

One of the objects of the present invention is to provide a control mechanism characterized by an electrically responsive system in which the movable elements are of such small mass that prompt response and a high frequency of reversal can be had. Another object of the invention is to provide a voltage-responsive control mechanism in which the frequency response is of the order of 5,000 to 10,000 cycles per second and sometimes even more. A further object of the invention is to provide a control mechanism which combines a voltage-responsive signal system with means forming a conduit for supplying a pressure fluid to a distributor in such manner that an electrically induced movement of very small magnitude within the control mechanism produces a movement of very large magnitude in a device such as a fluid pressure motor to which the distributor may be connected. Still a further object of the invention is to provide apparatus of the kind described having means for suspending the parts in such manner that this electrically induced movement can be obtained and communicated with a minimum of drag, backlash, etc.

Other objects and advantages of the invention will be apparent from the accompanying drawings, in which Figure 1 is a perspective of the control mechanism showing the housing, pressure fluid lines, leads, etc. Figure 2 is a plan with parts of the top plate and certain of the other elements broken away to reveal the details of construction. Figure 3 is an elevation with parts in section along line 3—3 of Figure 2. Figure 4 is a fragmentary elevation of those parts of the mechanism that are to be seen from line 4—4 of Figure 2.

As appears from Figure 1, housing 1 is in general a box-like unit of oblong shape supported by a standard 2 equipped at its lower end with a base plate 2a. Housing 1 consists of a bottom plate 3 by which it is attached to standard 2, a paralleling top plate 4, a

2

rear end piece 5, a front end piece 6 (seen in Figure 3), a near side plate 7, and a far side plate 8. As appears from Figure 2, side plate 7 is provided with an opening 7a for a first magnet assembly 9 and far side plate 8 is provided with a similar opening 8a for a second magnet assembly 9. Far side plate 8 also has a smaller opening 8b for a pipe nipple 10 forming part of the line supplying pressure fluid to the control mechanism. A coupling 11 serves as means for attaching to pipe nipple 10 a metal pipe 12 supplying a suitable pressure fluid, preferably oil, from a reservoir or other source maintained at substantially constant pressure.

At its inner end pipe nipple 10 has a threaded portion 13 which engages a correspondingly tapped inlet opening 15 in a metal block 14 which, seen from above, is more or less pentagonal in shape. Block 14 is supported by means of pipe nipple 10, coupling 11 and pipe 12. As can be seen from Figure 2, block 14 has two mutually inclined forwardly extending faces 14a and 14b which converge but do not meet, being interconnected at the forward end of the block by a concave face 14c of cylindrical shape. Inlet opening 15 extends into the interior of block 14, where it communicates with a central bore 16, best seen in Figure 3, the outer end of which is closed by a threaded plug 17. Bore 16 does not extend all the way through block 14 but terminates as shown at a point short of concave face 14c. In open communication with it is a narrow passage 18 that extends forwardly to concave face 14c where it is itself in communication with a narrow passage 19 of substantially the same cross sectional area in a cylindrical metal dowel 20 that is fastened in any suitable way, as by welding, to concave face 14c of block 14.

Directly forward of but spaced from dowel 20 is a smaller metal block 22 which, seen from above, is roughly triangular in shape. Triangular block 22 has at its rearwardly directed apex (Figure 2) a concave face 22a having approximately the same radius of curvature as concave face 14c of pentagonal block 14. Between dowel 20 and concave face 22a is a clearance of about one thousandth or at the most a few thousandths of an inch, sufficient to permit freedom of movement as between dowel 20 and triangular block 22. Formed in triangular block 22 and disposed in substantial alignment with passage 18 in pentagonal block 14 and passage 19 in dowel 20 is a narrow passage 23 of like cross-sectional area which at its forward end communicates with a forwardly extending bore 24 of larger size. Supported in bore 24 is a self-contained metal nozzle assembly consisting of a closely fitting cylindrical member 25, a mounting flange 26, and a forwardly directed conical element 27, all of which are preferably integral with each other. Within the nozzle assembly is a narrow passage 28 which tapers forwardly within conical element 27 and which terminates at the end thereof in orifice 29. For reasons which will appear hereinafter, a circular baffle 30 is mounted approximately midway between the ends of conical element 27, being held thereto by brazing or in some other convenient way.

Triangular block 22 is coupled to and supported from pentagonal block 14 by two pairs of crossed metal tapes, each such pair providing a pivotal support of the kind referred to as a "flexure pivot." The two pairs of crossed tapes are best seen in Figure 4. Those making up the upper pair, 31 and 32, and those making up the lower pair, 33 and 34, appear when seen from above or below to intersect at points in alignment with the axis of dowel 20. The tapes may be held to the blocks in any convenient manner, as by screws, spot welding or

3

the like. Where the upper tape of each pair crosses the lower tape of the same pair, the two are in contact, but such contact is little more than point contact. Bearings of this sort are known in the instrument art. The tapes are of such materials and dimensions and so related to each other and to the blocks to which they are attached as to provide the desired clearance (shown at 35 in exaggerated fashion in Figure 3) between dowel 20 and the concave face 22a of triangular block 22.

A channel-shaped strap 36 of flexible metal extends rearwardly from the top and bottom ends of triangular block 22, being held thereto by screws 37. It is out of contact with pentagonal block 14, which, as appears from Figure 3, is shorter than triangular block 22. Strap 36 forms a semi-circular loop between magnet assemblies 9. Rivets 38 serve to attach to the inside of the loop a winding carrier of the nature of a coil form 39, cylindrical in shape, that is preferably laminated of resin-impregnated paper. At its opposite ends, coil form 39 is provided with attenuated portions 40, one of which appears in cross-section in Figure 2. Surrounding coil form 39 at each of the two ends thereof where the coil form 39 is attenuated in the manner just described is a toroidal winding 41 which in the drawings is shown as made up of a single layer, but which in practice will usually consist of two or more layers of turns. In each case, attenuated portion 40 and coil 41 extends as shown in Figure 2 into a circular air gap 42 surrounding an inner pole piece 43 that forms part of magnet assembly 9.

Within the magnet assembly, suitably spaced from the end of coil form 39, a brass centering ring 44 is bonded by a metallic bond, preferably silver solder, to inner pole piece 43. Bonded in similar manner to inner pole piece 43 and in alignment therewith is a cylindrical magnet 45. To the latter, at its opposite end, is bonded a cap-forming pole piece 46. The latter is so shaped that it can be common to cylindrical magnet 45 and a surrounding ring magnet 47, to which pole piece 46 is held by a metallic bond or, if desired, by screws (not shown). Ring magnet 47 is provided at its inner end with a square pole piece 48 having a circular opening accommodating pole piece 43, coil form 39, and coil 41. A suitably shaped fibre insulating element 49 is mounted as shown in Figure 2 in a cut-away portion of outer pole piece 48. Pole piece 48 is held by screws 50 to the near side plate of housing 1, such screws being located as shown in Figure 3 in the areas between the circular center opening and the corners of pole piece 48.

The construction of the magnet assembly shown in cross section in Figure 2 is duplicated on the opposite side of housing 1. Thus there are two aligned magnet assemblies and, acting in opposition to each other, two coils 41, one at each end of coil form 39. Each of the two coils 41 has two leads, the same appearing in Figures 1 and 3. Leads 51 serving one of the two coils and leads 52 serving the other are surrounded by conventional shielding material where they pass through the opening 53 in the top plate 4 of housing 1 (Figure 3). A grommet 54 of rubber or other soft material is provided to grip the shielding material and thus keep the leads from moving about unnecessarily within housing 1.

Leads 51 and 52 are connected to the source of a suitable signal in the apparatus to be controlled; e. g., leads 51 may have impressed on them a voltage of a low degree of magnitude that is communicated to them from a first circuit forming part of the device while leads 52 may have impressed on them a voltage of a different order of magnitude that is communicated to them from a different circuit likewise forming a part of the device. In each case, variations in voltage will tend to produce mechanical movement of the coil to which the leads are connected, such movement being in a direction extending generally axially of the magnet assembly with which the coil on the coil form is associ-

4

ated. If a voltage is impressed on one pair of leads that is greater than the voltage impressed on the other pair, the greater voltage will of course control the movement, which will be the net or resultant movement; i. e. the algebraic sum of the two separate movements. The individual movements and the algebraic sum of the two will ordinarily be of the order of a few thousandths of an inch.

Movement of coil form 39 in either direction will of course produce a corresponding deflection of channel shaped strap 36 and, as a result, an opposite movement of triangular block 21 on the far side of the vertical axis of dowel 20. Because of the geometry of the parts, a small movement of coil form 39 is reflected in a still smaller movement of triangular block 20 and of the nozzle assembly that is mounted on it. As a result, nozzle element 27 and orifice 29, out of which the pressure fluid is constantly flowing in a steady stream, will move over a very small arc. If the control mechanism is balanced so as to make it possible, the two extreme positions will of course be on opposite sides of a vertical plane passing through the longitudinal axis of the control mechanism.

As shown in Figure 3, a distributor 56 is mounted in a rearwardly facing cylindrical opening in front end piece 6 of housing 1. Distributor 56 has in the mounted end thereof a tapped bore 57 in which is received the threaded portion of a tightening screw 58. The head 59 of the tightening screw can be reached and manipulated from an access opening 60 in the forward face of front end piece 6. By tightening screw 58, distributor 56 may be seated firmly in the rearwardly facing opening in front end piece 6. The opening will ordinarily be of a size just sufficient to accommodate the end of distributor 58 without permitting perceptible play.

As indicated in Figures 2 and 3, distributor 56 has two angled faces, 61a and 61b, which converge just forward of orifice 29. Face 61a, which is on the near side of distributor 56 as seen in Figure 3, has in apposition to orifice 29 an opening 62 that is in communication with a narrow passage 63 that extends as shown in dotted lines lengthwise of distributor 56. At its far end, passage 63 is closed by a threaded plug 63a. An intersecting passage 64 communicates with a passage 65 of like dimensions that is formed in front end piece 6 as indicated in Figure 3. At its lower end, passage 65 opens into a tapped outlet 66 in which is received the threaded end metal pipe 67 of a nipple 68. A coupling 69 connects the latter to a metal pipe 70 leading to a fluid pressure motor such as a cylinder and piston, extensible diaphragm or the like (not shown).

In face 61b of distributor 56 an opening similar to opening 62 is formed in juxtaposition to and on the same level as opening 62 in face 61a. Such opening, which does not appear in the drawings, communicates with a passage 71, shown largely in dotted lines, that is closed by a threaded plug 71a. Passage 71 is in communication with an intersecting passage 72 and a passage 73 formed in front end piece 6. The latter passage extends from distributor block 56 to a tapped outlet 74 which receives the threaded end 75 of a metal pipe nipple 76. To pipe nipple 76 is attached a coupling 77 for a metal pipe 78 that leads to the same fluid pressure motor as pipe 70. If such fluid pressure motor takes the form of a cylinder and piston, pipe 70 communicates with the cylinder on one side of the piston and pipe 78 with the same cylinder on the opposite side of the piston.

Any difference between the pressures in pipes 70 and 78 thus produces an unbalanced force moving the piston within the cylinder.

To the rear of front end piece 6 is a lower filler block 80 that is held in place by means of a screw 81 that extends upward through bottom plate 3. Above distributor 56 is a like upper filler block 82 that is held in place by a screw 83 extending downward through top plate 4.

5

When filler blocks 80 and 82 are in their intended positions, there is formed between them a chamber 84 which encompasses distributor 56. This chamber tends to fill with the pressure fluid that is being projected from orifice 29 in the nozzle assembly mounted on triangular block 22.

In order to retain the pressure fluid within the chamber insofar as possible and to keep it from becoming mixed with air, two opposed baffles 85 and 86, the former provided with a semi-circular opening 85a and the latter with a semi-circular opening 86a, project toward each other from lower and upper filler blocks 80 and 82, respectively. To the rear thereof is baffle 30 on nozzle element 27. Below and above it, two spacers 87 and 88 back up baffles 85 and 86. To the rear of spacers 87 and 88 are two retaining plates 89 and 90 which are of somewhat heavier gauge than baffles 85 and 86 but, like them, are provided with semi-circular openings 89a and 90a. Screws 91 are employed to hold the plates, spacers and baffles to the filler blocks.

Pressure fluid of course escapes from chamber 84 by way of openings 85a and 86a in baffles 85 and 86 and by way of openings 89a and 90a in retaining plates 89 and 90. The escaping pressure fluid drains downward to the top of bottom plate 3, where it would accumulate were it not for the presence therein of a tapped waste opening 92 having connected thereto a metal pipe nipple 93, a coupling 94 and a waste pipe 95. Some of the pressure fluid supplied by pipe 12 also escapes through clearance 35 between dowel 20 and triangular block 22, draining down between them to the top of bottom plate 3 and discharging to a waste line by way of outlet 92, nipple 93, coupling 94 and pipe 95.

In the operation of the control mechanism, pressure fluid such as oil at a pressure of about 100 lb./sq. in. is admitted by means of pipe 12. From pipe 12 it proceeds through inlet 15, bore 16 and passage 18 in pentagonal block 14 to passage 19 in dowel 20. Notwithstanding clearance 35, from which a small fraction escapes, most of it enters passage 23 in triangular block 22, from which it proceeds into bore 24 and thence into passage 28 in the nozzle assembly. From the latter it is discharged in the form of a steady stream through orifice 29. As indicated in Figures 2 and 3, orifice 29 is directed at but somewhat spaced from distributor 56, against which the stream of pressure fluid impinges.

When the control mechanism as a whole is balanced; that is to say, when the parts are in their neutral positions, the pressure fluid discharged through orifice 29 is divided equally between opening 62 in face 61a of distributor 56 and the like opening (not shown) in face 61b. In consequence, the pressure is the same in passages 63 and 71 and therefore in the passages, bores and pipes that connect passages 63 and 71 to the fluid pressure motor. If, as in the usual case, the fluid pressure motor takes the form of a cylinder and piston, the pressures on the opposite faces of the piston will be equal. If the piston faces are of equal area, the piston will remain stationary between the ends of the cylinder. This condition will obtain as long as there is no movement of coil form 39.

If, however, a condition of unbalance in the control mechanism is set up as the result of the receipt through leads 51 or leads 52 of an electrical signal; viz., a change in voltage, coil form 39 moves to one side or the other of its neutral position between magnet assemblies 9. Movement of coil form 39 is communicated by strap 36 to triangular block 22, the latter swinging in a small arc about the axis of dowel 20 or, more accurately stated, about the line interconnecting the intersections of the upper and lower pairs of crossed tapes. This arcuate movement of triangular block 22, which is of course in a direction opposite to the direction of movement of coil form 39, results in movement of the nozzle assembly and therefore of orifice 29 in nozzle element 27.

If it is assumed that coil form 39 moves toward far side plate 3, triangular block 22 moves toward near side

6

plate 7. In consequence, the stream of pressure fluid emanating from orifice 29 impinges with greater effect on opening 62 in face 61a of distributor 56 than on the corresponding opening in face 61b. As a result, the pressures on the opposite faces of the piston forming a part of the fluid pressure motor will be unequal. The piston will therefore move out of its neutral position, thus providing translatory movement of a piston rod or other element that can be used to control the position of a part such as a valve or the like in the apparatus with which the control mechanism is being used.

In the system shown and described, coils 41 are sensitive to extremely small changes in the signal with corresponding movement of the parts in the manner already explained. The frequency response is between 5,000 and 10,000 cycles per second, which is vastly greater than the frequency response of prior control mechanisms. The most sensitive of the latter is understood to have a frequency response of the order of some hundreds of cycles per minute. The mass of those elements which move in the operation of the control mechanism is small and reversal of direction of movement is easily and quickly accomplished. In consequence a duty cycle for a given instrumentality can be established and maintained without difficulty.

The materials used for the parts of a control mechanism made as shown and described will depend on in part the location of the part or parts in the mechanism. In general, the top plate, bottom plate, side plates and rear end piece will be of non-magnetic material such as aluminum, brass or the like. The pole pieces of the assemblies will be of steel or soft iron, while the cylindrical magnets and the surrounding ring magnets that intervene between the pole pieces will preferably be of an alloy having an especially high flux density; for example, the sintered material known as Alnico V, which is understood to be a precipitation hardened alloy of aluminum, nickel, cobalt, copper and iron. The centering ring will preferably be of brass. The coils are preferably of #32 or 34 wire, plastic insulated, in two layers of 23 turns wound on a coil form 2 in. in diameter. The strap connecting the coil form and the triangular block will normally be of aluminum or of like material having a thickness of 0.020 to 0.025 inch. The pentagonal block, the triangular block, the connecting tapes, the dowel, the nozzle assembly and the various other parts of the apparatus, including the distributor, may be of steel, brass or any other convenient material. In general, the use of non-magnetic material is required only in those parts which are located in the magnetic field or are in immediate proximity to it; e. g., the top, bottom and side plates of the housing.

Departures from what has been shown and described, particularly in the arrangement of parts, may readily be made and the foregoing description and accompanying drawings should therefore be taken as illustrative rather than as limitative of the invention.

A control mechanism of this kind has many potential uses, as, for example, in known systems for controlling the edge of a traveling web of paper that is being wound into roll form on a cylinder. An electric eye and a circuit appropriate to it may be used to "sense" the position of the edge of the web of paper, the signal being communicated as described to a coil mounted on a coil form in the field of a permanent magnet. The latter may be opposed by another coil or by a diaphragm, spring, dash pot or the like. Deviations from the intended position of the edge of the web of paper being wound will produce variations in the signal being communicated by the electric eye to the control mechanism, which responds to make an appropriate change in the position of the cylinder on which the web of paper is being collected. This illustration of a potential use for the control mechanism of the present invention is simply

one of many possible uses that will suggest themselves to those skilled in the art.

It is intended that the patent shall cover, by suitable expression in appended claims, all features of patentable novelty that reside in the invention.

What is claimed is:

1. A device for translating an electrical impulse of small magnitude into a force of large magnitude comprising a supporting structure; a distributor associated therewith; a distributor within the housing having connections for coupling the distributor to an element responsive to fluid pressure; means forming an orifice directed at but spaced from the distributor; means interconnected therewith forming a conduit for supplying a pressure fluid to the orifice; a pair of opposed bearings of the flexure type, one on each side thereof, providing point support for the means forming the conduit; a magnet supported from the supporting structure; an electrical winding disposed in the path of the lines of force of the magnet, said winding being carried by a moveable winding carrier; and, for communicating movement of the winding carrier to the means forming the conduit, means coupling the former to the latter.

2. A device for translating an electrical impulse of small magnitude into a force of large magnitude comprising a housing; a distributor within the housing having connections for coupling the distributor to an element responsive to fluid pressure; means forming an orifice directed at but spaced from the distributor; means interconnected therewith forming a conduit for supplying a pressure fluid to the orifice; a pivotal support for the means forming the conduit; a plurality of coaxially arranged electrical windings of the nature of coils, each of which is provided with leads of its own, mounted on a single moveable coil form; magnetic means rigidly mounted on the housing in such relation to the coil form that the lines of force emanating from the magnetic means are cut by the windings on the coil form; and, for communicating movement of the coil form to the means forming the conduit, means mechanically interconnecting the former and the latter.

3. A device for translating an electrical impulse of small magnitude into a force of large magnitude comprising a housing; a distributor within the housing having connections for coupling the distributor to an element responsive to fluid pressure; means forming an orifice directed at but spaced from the distributor; means interconnected therewith forming a conduit for supplying a pressure fluid to the orifice; a pivotal support for the means forming the conduit; two opposed electrical windings of the nature of coils, each carried by moveable coil-forming means; mechanical elements rigidly attached to the coil-forming means for communicating movement of the coil-forming means to the means forming the conduit; and, rigidly mounted on the housing, two opposed magnets each of which provides a magnetic field embracing the nearer of the two opposed electrical windings, said magnets being aligned with each other along an axis extending transversely of the housing.

4. A device as in claim 3 in which the two windings take the form of toroidal coils aligned with each other along an axis extending transversely of the housing.

5. A device as in claim 4 in which the windings and magnets are aligned with each other along a common axis extending transversely of the housing.

6. A device for translating an electrical impulse of small magnitude into a force of large magnitude comprising a housing; a distributor within the housing having connections for coupling the distributor to an element responsive to fluid pressure; means forming an orifice directed at but spaced from the distributor; means interconnected therewith forming a conduit for supplying a pressure fluid to the orifice; two opposed bearings, one on each side thereof, for moveably supporting the means forming the conduit; a single movable coil form mounting two opposed electrical coils, each provided with leads of its own; strap-like means coupling the coil form to the means forming the conduit; and, rigidly mounted on the housing, two opposed magnets each of which provides a magnetic field embracing the nearer of the two opposed electrical coils.

7. A device as in claim 6 in which each of the two bearings provides point support for the means forming the conduit.

8. A device as in claim 7 in which the bearings employ crossed elements to provide the point support for the means forming the conduit.

9. A device as in claim 8 in which the bearings are of the flexure type.

10. A device for translating an electrical impulse of small magnitude into a force of large magnitude comprising a housing; a two-way distributor within the housing having connections for coupling the distributor to an element responsive to fluid pressure; nozzle means having an orifice directed at but spaced from the distributor; means interconnected therewith forming a conduit for supplying a pressure fluid to the nozzle means; a plurality of opposed bearings of the flexure type, one on each side thereof, moveably supporting the means forming the conduit; two permanent magnets of high flux density mounted on the housing in opposed relation to each other; and, disposed in the path of the lines of force of the magnets, two toroidal electrical windings, both of said windings being mounted on a single form that is coupled by a strap to the means forming the conduit.

References Cited in the file of this patent

UNITED STATES PATENTS

1,105,924	Pridham	Aug. 4, 1914
1,734,944	Green	Nov. 5, 1929
1,784,517	Farrand	Dec. 9, 1930
2,269,072	Wilde et al.	Jan. 6, 1942
2,298,112	Edwards et al.	Oct. 6, 1942
2,350,808	Peglau	June 6, 1944
2,503,243	Cohen	Apr. 11, 1950
2,601,207	Jacques	June 17, 1952
2,601,867	Alyea	July 1, 1952
2,699,356	Ziebolz	Jan. 11, 1955

FOREIGN PATENTS

689,814	France	June 2, 1930
---------	--------	--------------