Oct. 13, 1953 R. SCHEIB, JR 2,655,132

LINEAR MOTION MAGNETIC MOTOR

Filed April 2, 1948 2 Sheets-Sheet 1

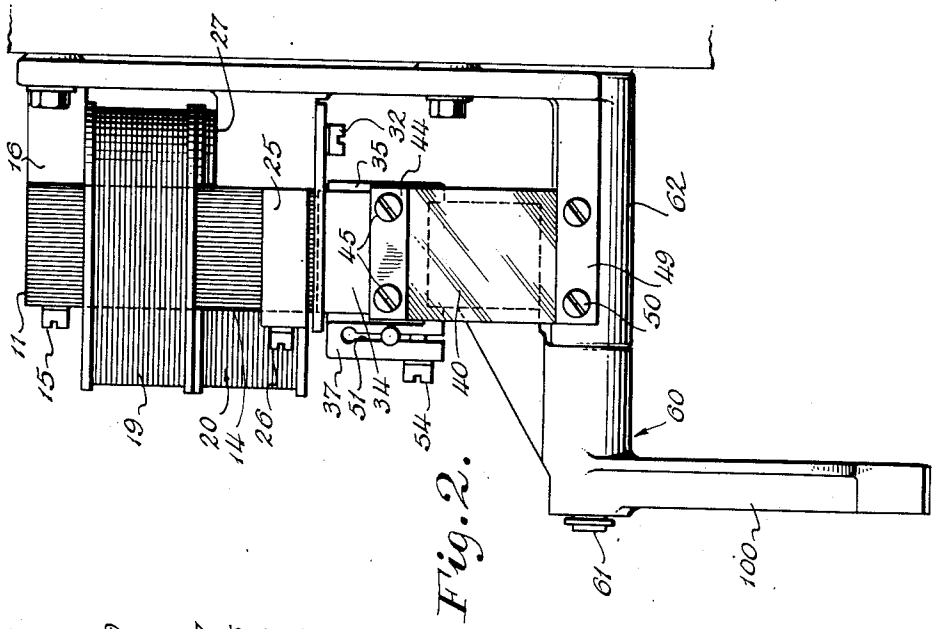


Fig. 2.

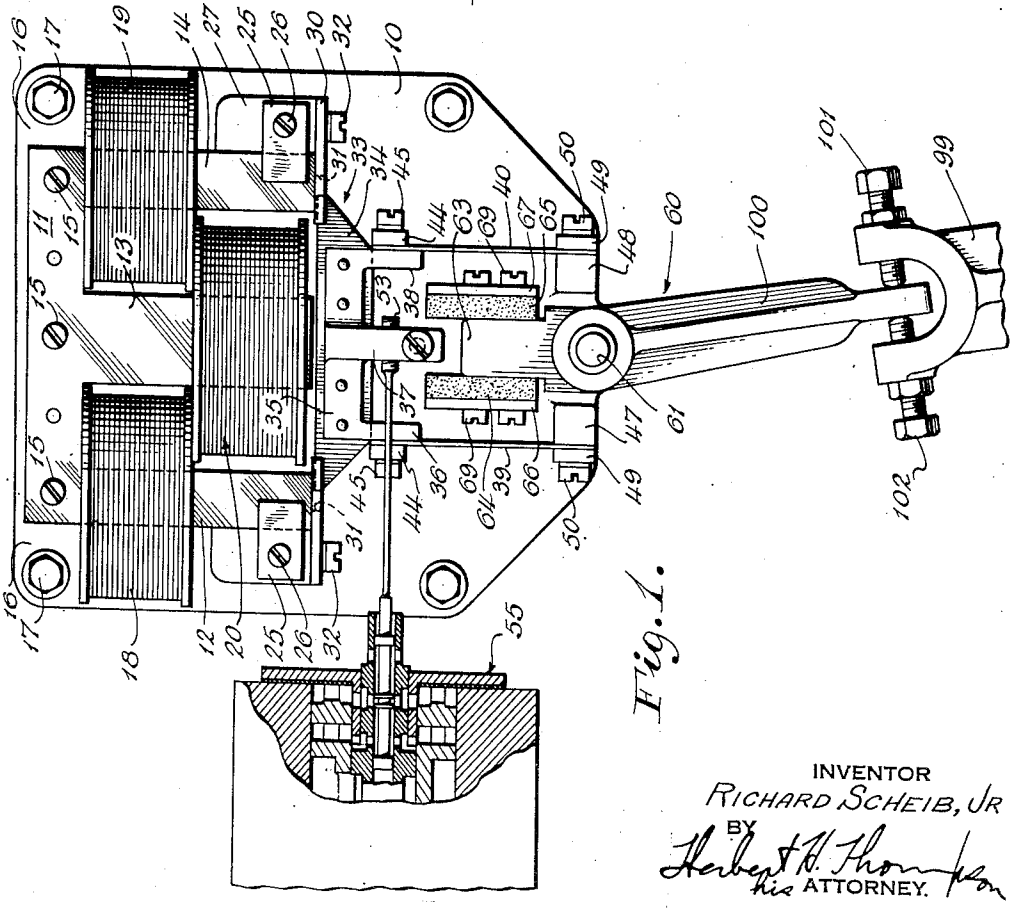


Fig. 1.

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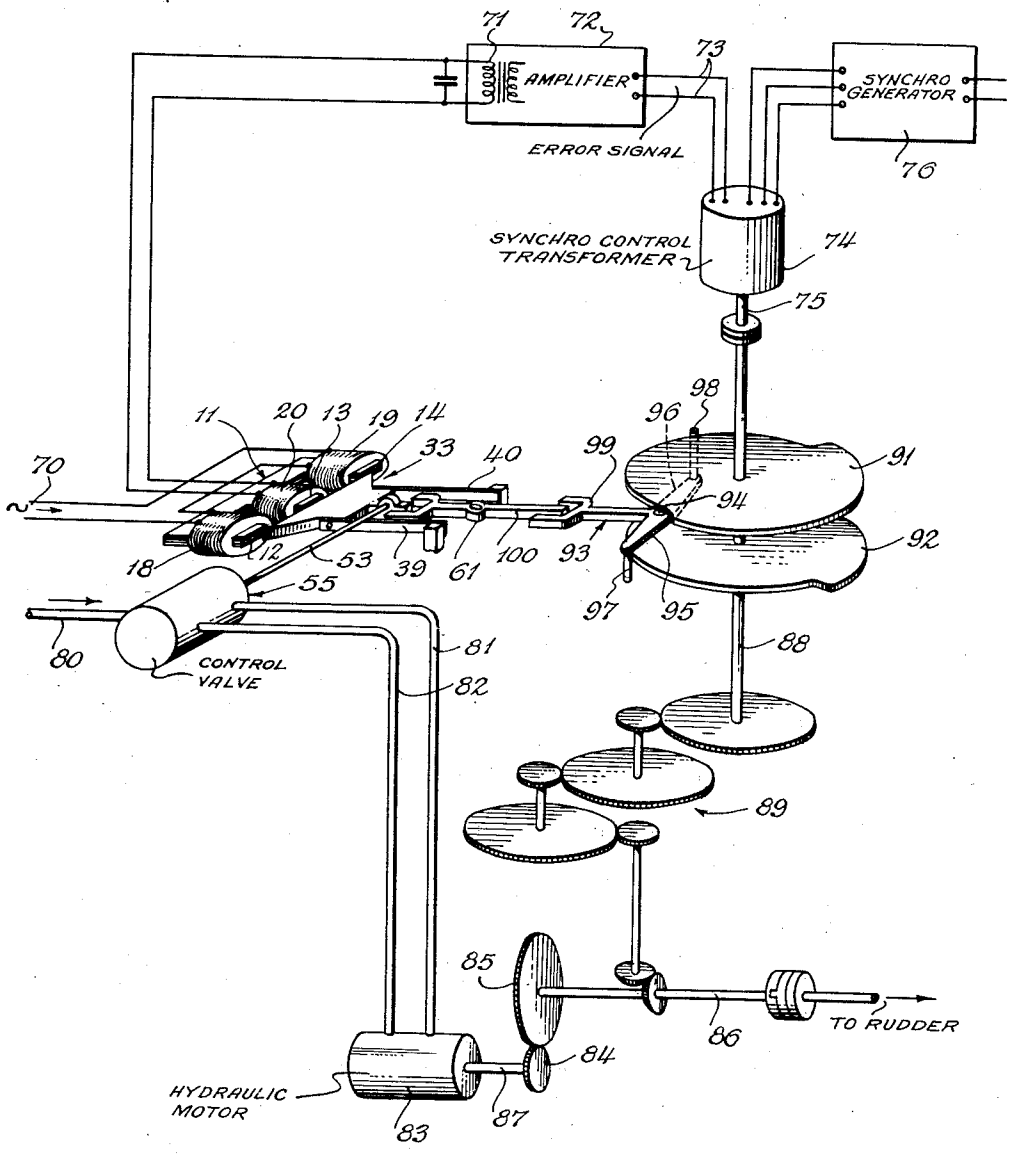


Fig. 3.

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LINEAR MOTION MAGNETIC MOTOR

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4 Claims. (Cl. 121—41)

1

This invention relates to an electro-magnetic motor having a controllable linear output motion particularly suitable for operating control valves of hydraulic apparatus and the like.

In a preferred embodiment, the invention provides a simple electro-magnetic control apparatus designed to be "fail safe" that is, an element controlled by the apparatus is displaced automatically to neutral position on the failure of any operating voltage or on the disabling of any of the control circuits therefor.

Another object of the invention is the provision of a control apparatus suitable for use with automatic pilots.

Another object of the invention is the provision of a simple electro-magnetic motor designed for operation directly from low voltage alternating current sources and in which pivots, and joints, and the backlash and lost motion therefrom are eliminated.

A further object of the invention is to provide a control system for an automatic pilot for ships which avoids the use of high positive potentials such as those of direct current amplifier anode circuits which in the damp sea air are objectionable due to the difficulty of avoiding electrolytic action. Direct current systems usually employ some differential output arrangement controlled by anode circuits of a pair of vacuum tubes which do not "fail safe" because failure of one tube, or breaking of an output wire will cause a rudder or other control surface to be swung hard over. In the present invention, such mishaps cause a member, such as a pilot valve to be automatically displaced to its neutral position without disturbing the angle of the rudder at the instant of failure.

Other objects and features will be found in the following description given with the aid of the accompanying drawings, of which

Fig. 1 is a plan view of an electro-magnetic motor in accordance with a preferred embodiment of the invention;

Fig. 2 is a side view; and

Fig. 3 is a schematic drawing illustrating the use of the present invention with a hydraulic apparatus for controlling the rudder of a ship.

In a preferred form of the invention, shown in Figs. 1 and 2 of the drawings, a base 10 supports a laminated E-shaped polepiece 11, having arms 12, 13 and 14. The polepiece is secured by screws 15 to a bracket 16 which is fastened by screws 17 to base 10. Field windings 18 and 19 are mounted respectively on arms 12 and 14 of the polepiece and a control winding 20 is disposed on the center arm 13. In order to provide a more compact

2

structure, the spool of control winding 20 partially overlaps the spools holding the field windings. Near their outer ends, the arms 12 and 14 are clamped to base 10 by respective angle pieces 25 which are attached by screws 26 to brackets 27 disposed under the outer portions of arms 12 and 14 and secured to base 10.

Slotted guide plates 30 of suitable material are positioned over the ends of each of the outer arms 12 and 14 of the polepiece with the slots indicated by dotted lines 31 facing each other. The guide plates are secured to brackets 27 by screws 32. The width of the slots corresponds approximately to that of the arms of the polepiece, and the slotted guide plates serve to prevent displacement of an armature 33 in a direction perpendicular to the normal motion when the equipment is subjected to shocks. The armature is made up of laminations 34 sufficiently long to overlap a portion of each of the ends of the arms 12 and 14 of the polepiece. The laminations are clamped in a slot in a supporting member 35 which is formed, as shown in Fig. 1 with three depending arms 36, 37 and 38. Flat springs 39 and 40 for supporting and centralizing the armature are respectively fastened at one end to arms 36 and 38 by corresponding cleats 44 and screws 45 while the opposite ends of the springs are attached to spaced posts 47 and 48 formed integrally with base 10 by corresponding cleats 49 and screws 50. The supporting arrangement for the armature permits limited endwise displacement thereof in either direction from a neutral position in accordance with the energization of the control winding 20 as will be described.

One side of the center arm 37 of the supporting member 35 projects forwardly beyond the rest of the armature structure as shown in Fig. 2, and this projection portion has a slot 51 cut therein extending across a threaded opening 52 which serves as a clamp for a threaded spindle 53 connecting the armature with the device to be controlled. A screw 54 is threaded in the arm across the slot for purpose of closing the slot to tighten the clamp. In Fig. 1 spindle 53 is shown as being connected to a pilot valve 55 of a hydraulic system. Such hydraulic apparatus is well known and therefore it is not thought necessary to describe the details thereof, beyond stating that a small movement, in one direction or another from a neutral position, for example .03" is adequate to control known pilot valves and such movement is available from the motor just described.

A lever 60 pivoted on a stub shaft 61 mounted on a post 62 formed on base 10 has an arm 63

disposed immediately below the center arm 37 of the member 35. This lever is part of a linkage used in connection with a mechanical limit stop arrangement described below. The arm 63 of the lever has blocks of synthetic rubber 64 and 65 secured on opposite sides thereof supported by backing plates 66 and 67 which are attached to the lever arm 63 by screws 69. The motor usually runs in oil, hence the blocks are made of synthetic rubber. The rubber blocks are positioned on opposite sides of arm 37 and so spaced as to be normally out of contact therewith, but when the lever is turned in either direction by a limit stop cam arrangement, to be described, one or the other of the synthetic rubber blocks will be brought into engagement with the appropriate side of arm 37, and continued rotation of the lever will force the armature and the member controlled thereby back to their neutral positions. The rubber blocks are for the purpose of damping excessive hum vibration in the armature when it is thus coerced by the lever.

A mechanical limit stop arrangement for controlling lever 60 is shown schematically in Fig. 3 together with a circuit arrangement for the electro-magnetic motor and a portion of a hydraulic apparatus which might be used with an automatic pilot for steering a ship. In Fig. 3, field coils 18 and 19 are shown connected in series and excited by a source of alternating current 70. When the field windings are thus excited and the control winding 20 is not energized, the flux from the field windings flows through the outer arms of the polepiece and through the armature and aids the armature springs in centralizing the armature. This magnetic centralizing force for zero control winding excitation is many times the spring centralizing force. No flux is evident in the central arm 13 of the polepiece under the circumstances. When the control winding is energized the resulting flux in arm 13 unbalances the flux created by the field winding and causes the deflection of the armature, the magnitude and direction of which depends on the magnitude of the signal and the relative phase thereof with respect to the current exciting the field windings. Maximum forces are obtained from the motor when the phase of the control winding is identical to the phase of the field windings. In the arrangement disclosed herein, where the motor is used to control a pilot valve, resistance of the valve to the motion of the motor sets up a hum vibration in the armature which is utilized to dither the valve.

The control winding 20 is shown connected across the secondary winding of an output transformer 71 of an amplifier 72. This circuit arrangement eliminates the use of high voltage anode circuits required for direct current controlled devices for the same purpose.

The input circuits 73 of the amplifier are connected to the secondary winding, which is a rotor winding, of a synchro control transformer 74. The rotor of the latter has a shaft 75. The primary stator windings of the synchro control transformer 74 are connected with the output of a synchro generator 76 which may be controlled manually, or by the output of a suitable automatic pilot (not shown).

By way of example, the armature 33 as shown in Fig. 3 operatively connected to a valve 55 having a fluid input pressure circuit 80 and output pressure circuits 81 and 82 selectably controlled thereby. Circuits 81 and 82 drive a reversible hydraulic motor 83 which operates a rudder control shaft 86 through a train of mechanism including a gear 84 fixed on shaft 87 of the motor, and a gear 85 in mesh therewith which is fixed to shaft 86, the latter being operatively connected to a steering engine or rudder (not shown).

In accordance with known practice, an example of which is shown in the patent to Frische et al., 2,415,430, for Automatic Pilots, dated February 11, 1947, control signals from a synchro generator or selsyn transmitter 76, governed by the gyro compass and/or by hand, induces error signals in the rotor winding of the synchro control transformer or selsyn signal generator 74 and the error signals control amplifier 72 which signals are proportional to deviation from course or a desired course change, and are fed into winding 20 of the electro-magnetic motor effective to actuate valve 55 and the motor 83 in the appropriate direction. A followup system connected with the shaft of the motor drives the shaft 75 of the synchro control transformer in such direction as to reduce the error signal to zero whereupon the armature 33 of the electro-magnetic motor assumes its neutral position and thus stops further operation of hydraulic motor 83 until further error signals are produced by the synchro control transformer. The follow up system includes a train of reduction gears and shafts 89 driven from shaft 85 and geared to shaft 88, the latter being coupled with the rotor shaft 75 of the synchro control transformer 74.

A mechanical limit stop cam device which limits the displacement of the rudder to predetermined angular distances on either side of a neutral position is controlled by a pair of adjustable cams 91 and 92 mounted in spaced relation on shaft 88.

A T-shaped lever 93 is mounted on a pivot 94 disposed between the cams. The cross arms 95 and 96 of lever 93 have pins mounted in the ends thereof, pin 97 being in the path of cam 92 while pin 98 is in the path of cam 91.

The cams 91 and 92 are adjustably secured to shaft 88 by means not shown and are so positioned thereon that predetermined rotation of the shaft in one direction, for example, in a clockwise direction, will bring cam 92 into engagement with pin 97, and continued movement of the cam will displace pin 97 and rock lever 93 about its pivot 94 in a clockwise direction. This occurs when the rudder is approaching its maximum preselected displacement. Rotation of the shaft 88 through a predetermined angular distance in a counter clockwise direction causes cam 91 to displace pin 98 and rock the lever 93 in a counter-clockwise direction.

An arm 99 of lever 93 is bifurcated, and the arms of the forked portion are positioned on opposite sides of the arm 100, Fig. 1, of lever 60 to which it is operatively coupled by set screws 101 and 102, the arrangement being such that lever 93 when rocked turns lever 60 on its pivot, and continued movement of the levers in either direction is effective to bring one or the other of the rubber pads 64 or 65 into engagement with the arm 37 fixed to the armature and ultimately coerce the armature back to its neutral position thereby moving valve 55 to cut off the actuating fluid for motor 83.

Shaft 88 is coupled with known manually controlled apparatus, not shown, such as a steering engine trick wheel, in order that the vessel may be steered by hand when the servo system is not running. The cams 91 and 92 and the lever arrangement controlled thereby are designed to

permit the shaft 88, when thus manually controlled, to overtravel the limits for which the cams are set without damaging the apparatus.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrated and not in a limiting sense.

What is claimed for:

1. In a servo system including a pilot valve and a motor controlled thereby, apparatus for actuating the pilot valve comprising a member of magnetic material formed with a pair of polepieces having a gap therebetween, an armature overlapping the gap coupled with the pilot valve, yielding means for supporting the armature for limited endwise movement in either direction from a neutral position, a field winding for the member, a constant source of alternating current for exciting the field winding, a control winding, a variable source of alternating current therefor effective to displace the armature, and means comprising a linkage mechanism actuated by the motor for restoring the armature to its neutral position for the purpose of preventing the operation of the motor beyond predetermined limits.

2. In a servo system including a pilot valve and a motor controlled thereby, apparatus for actuating the pilot valve comprising an E-shaped polepiece, an elongated armature partially overlapping the outer arms of the polepiece coupled with the pilot valve, a centralizing support for the armature permitting limited endwise movement thereof in either direction from a neutral position, serially connected field windings for the outer arms of the polepiece, a constant source of alternating current for exciting the field windings, a control winding on the center arm of the polepiece, a variable source of alternating current connected thereto for displacing the armature, a motion limiting device actuated by the motor, and means controlled by the limiting device for coercing the armature to its neutral position.

3. In a servo system including a pilot valve and a motor controlled thereby, alternating current actuated means for dithering the valve by the inherent hum therein and operating the valve according to the output displacement thereof which comprises an E-shaped polepiece, an elongated armature partially overlapping the ends of the outer arms of the polepiece coupled with the pilot valve, a centralizing support for the armature comprising a pair of flat springs, permitting limited endwise displacement thereof in either direction from a neutral position, serially connected field windings on the outer arms of the polepiece, a constant source of alternating current for exciting the field windings, a control winding on the center arm of the polepiece, a variable source of alternating current connected thereto for displacing the armature, a motion limiting device actuated by the motor, a member extending from the armature, and a lever controlled by the limiting device adapted to engage the member and coerce the armature to its neutral position.

4. In a servo system including a pilot valve and a motor controlled thereby, the improvement which comprises alternating current actuated means effective to dither the valve by the inherent hum vibration thereof and to operate the valve in accordance with the output displacement thereof which includes an E-shaped polepiece, an elongated armature partially overlapping the ends of the outer arms of the polepiece operatively connected with the pilot valve, flat springs attached to the armature near opposite ends thereof projecting at substantially right angles therefrom for centralizing and supporting the armature for limited endwise displacement from a neutral position, a constant source of alternating current for exciting the field windings, a control winding disposed on the center arm of the polepiece, a variable source of alternating current connected thereto for displacing the armature, an arm projecting from the armature, a mechanical limit stop mechanism controlled by the motor including a lever having one end in approximate register with the end of the arm, a pair of blocks supported in spaced relationship on said end of the lever on opposite sides of the arm but normally out of contact therewith, one or the other of the blocks being adapted on displacement of the lever to engage the arm and coerce the armature to its neutral position.

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