March 17, 1964 P. G. REUTER 3,125,000

AIRFOIL CONTROLLING ACTUATOR

Filed July 13, 1961 2 Sheets-Sheet 1

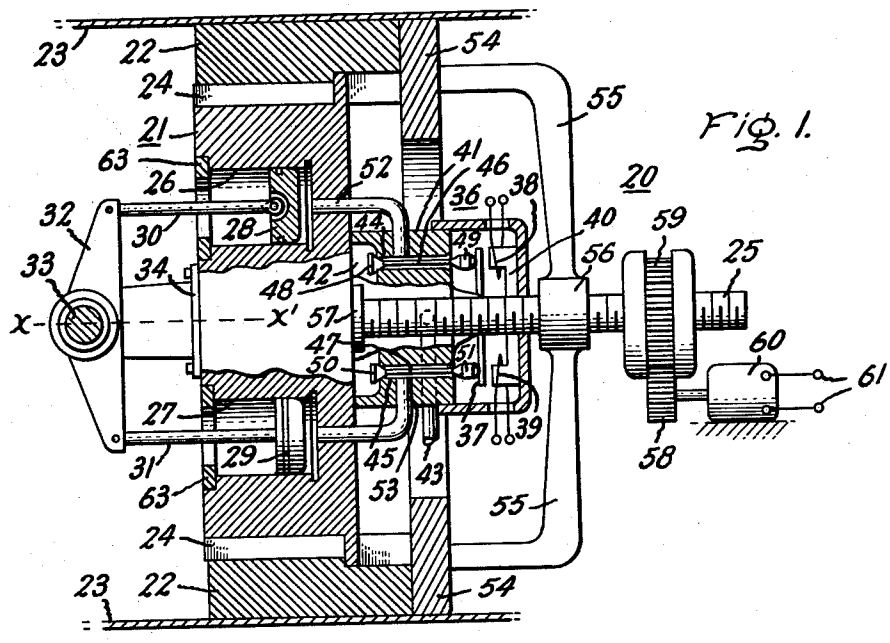

Fig. 1.

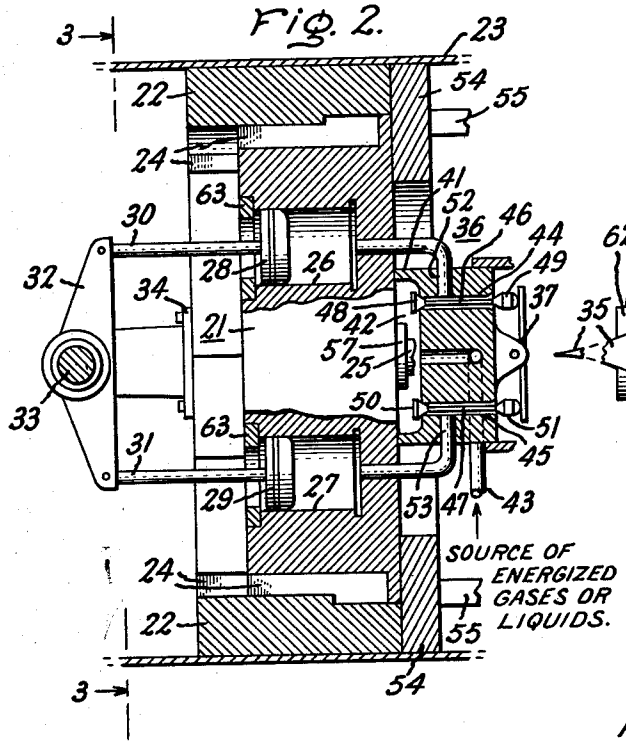

Fig. 2.

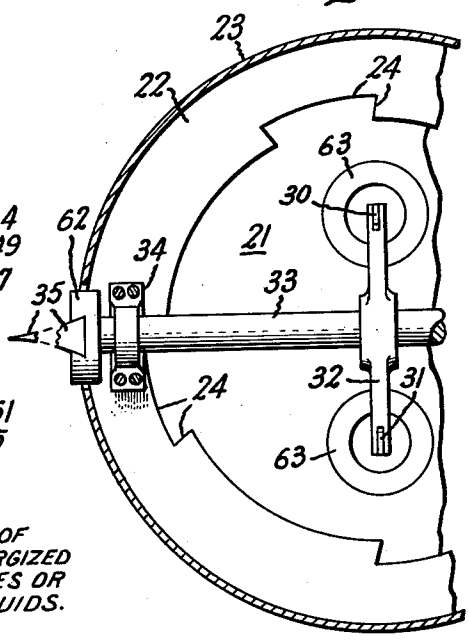

Fig. 3.

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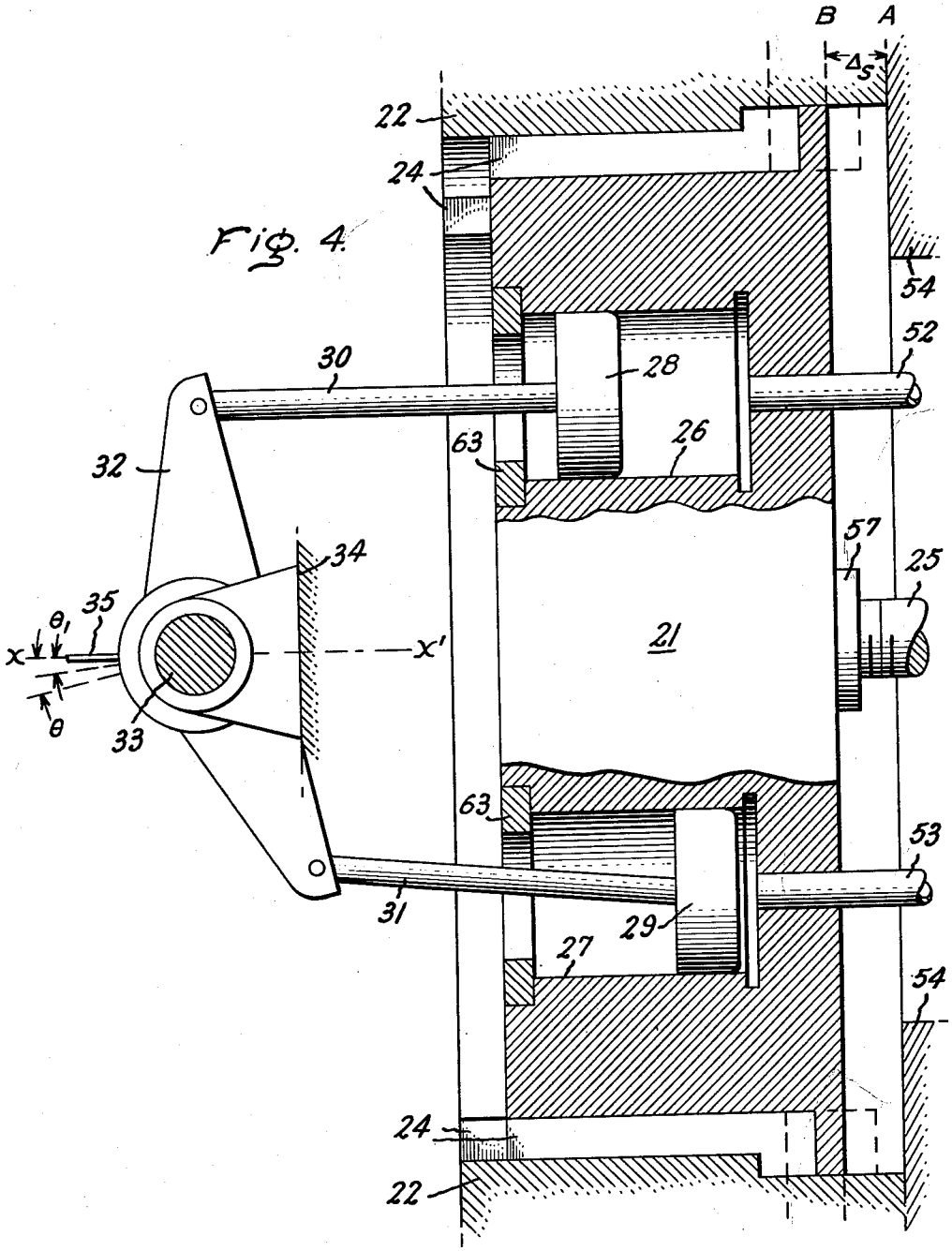
Fig. 4.



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United States Patent Office 3,125,000 Patented Mar. 17, 1964

3,125,000

AIRFOIL CONTROLLING ACTUATOR

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Filed July 13, 1961, Ser. No. 123,802
6 Claims. (Cl. 91—186)

This invention relates, in general, to actuators, powered by energized gases or liquids, useful for, inter alia, controlling the position of a load element in a servo mechanism system. More particularly, the actuator of this invention is an improvement over the hot gas servo actuator described, illustrated and claimed in the patent application of Howard W. Avery, Serial No. 863,256, filed in the United States Patent Office on December 31, 1959; rights with respect to the Avery invention and with respect to this invention having been assigned to the same assignee.

As is described in the Avery patent application, hereinbefore identified, a piston-and-cylinder type actuator is provided wherein two piston rods, coupled with a pivoted linkage member, are driven in push-pull fashion to cause the linkage member to be rotated through a limited arc about its pivot point. A load element, such as an airfoil, is coupled with the rotatable linkage member and is positioned in accordance with the movements of the pivoted linkage member. Operationally, three position attitudes are enabled. The airfoil may be positioned at either extremity of its limited arc of movement, or it may be placed in a neutral position, midway between these extremities. For example, a guide fin on a missile may be positioned in a "full-up" position; a "full-down" position; or, a neutral position, midway between the "full-up" and "full-down" positions. However, in many flight-control application there exists the need to position airfoils in an infinite number of position attitudes.

Therefore, the objects of this invention include: the provision of an actuator for enabling a load element (e.g., an airfoil) to be positioned in an infinite number of position attitudes, within the extremities of the load element's greatest range of movement; and, the provision of a relatively simple and economical actuator which is capable of performing the aforementioned positioning function reliably.

These objects, among others, are realized by the actuator of this invention. Briefly, in a piston-and-cylinder type actuator, employing a pair of push-pull driven piston rods coupled with a fixedly piovted common linkage member for rotating the common linkage member through a limited arc about its fixed pivot, there is provided a movable piston-receiving cylinder block and means for varying the position of the movable cylinder block relative to the fixed pivot whereby the arc length through which the common linkage member rotates is correspondingly varied. A load element, such as an airfoil, coupled with the common linkage member is, correspondingly, rotated through a variable arc length.

A fuller appreciation of the invention, as well as its advantages, will be realized by referring to the following detailed description, and claims, read in connection with the accompanying drawings, in which:

FIGURE 1 is a side view, partly in section, of a piston-and-cylinder type actuator embodying this invention;

FIGURE 2 is a side view, partly in section, of the actuator showing the movable cylinder block portion thereof at a position different from that shown at FIGURE 1;

FIGURE 3 is a partial view of one end of the actuator shown in the FIGURES 1 and 2; and,

FIGURE 4 is a view of the actuator showing various position attitudes of an airfoil coupled therewith, corresponding to various positions of the movable cylinder block.

Designated, generally, by the reference numeral **20** is the piston-and-cylinder type actuator provided by this invention. A cylinder block unit comprising two portions is provided: a movable cylinder block portion **21** is arranged within a fixed cylinder block portion **22** so that it may be slideably positioned therewithin. The cylinder block portion **22** is mounted in a fixed position on a supporting frame **23**; for example, a suitable mounting structure on a guided missile. The Avery patent application, hereinbefore identified, provides description, and illustration, suggestive of a suitable way of mounting the actuator of this invention.

In order to constrain the cylinder block portion **21** so that it may be moved along the axis X—X' (FIGURE 1) only, the cylinder block portions **21** and **22** are suitably keyed. The reference numerals **24**, shown at FIGURE 3, indicate the keyed nature of the slideable coupling between the fixed and movable cylinder block portions. Advantageously, the fixed cylinder block portion **22** may be a ring-like structure, as illustrated at FIGURE 3, which permits the movable cylinder block portion **21** to be positioned coaxially within the ring-like block portion **22**. A motor-driven lead screw **25**, fixed to the movable cylinder block portion **21**, positions the movable portion **21** within the fixed portion **22** in accordance with a suitable command, or error, signal.

Within the movable cylinder block portion **21** are the two bores **26** and **27**: the bore **26** receives the piston **28**; the bore **27** receives the piston **29**. Connected to the pistons **28** and **29** are the piston rods **30** and **31**, respectively; the ends of the piston rods being coupled, as illustrated, to opposite ends of a crossbar **32**. Thus, the crossbar **32** is arranged so that it may be pivoted through a limited arc length about a pivot means, shaft **33**, passing through the center of the crossbar; the shaft **33** being fixed with the crossbar **32** so that a rotational motion, only, of shaft **33** is enabled by the pivotal movement of the crossbar **32**. As is illustrated at FIGURE 3, the shaft **33** is supported by means of a suitable journal member **34** which is fastened to the fixed cylinder block portion **22**. Coupled with the shaft **33** is an airfoil **35**, illustrated, in part, at FIGURES 3 and 4.

Mounted on the movable cylinder block **21**, and movable therewith, is an electrically-actuated valve assembly, designated, generally, by the reference number **36**. The valve assembly functions in the manner hereinafter described to admit, or exhaust, an energized working substance to, or from, the bores **26** and **27** in the movable cylinder block portion **21**. In effect, the valve assembly **36** amounts to a double-poppet valve controlled by a torque motor, the same as is described, and illustrated, in the Avery patent application hereinbefore identified; the torque motor unit being a center-pivoted armature **37** which is moved in see-saw fashion by the selective energization of the control coils **38** and **39**, wound about the magnetizable pole-piece structure **40**. As is illustrated at FIGURE 2, the valve body **41** has five bores therein and a main chamber **42**. An inlet bore **43** is suitably coupled to a source of energized gases, or liquids, (not illustrated, but labeled as such at FIGURE 2) so that the source gases, or liquids, can be conducted to the main chamber **42**. The bores **44** and **45** receive the end flared stems **46** and **47**, respectively. The stem **46** has the flared ends **48** and **49** at opposing ends thereof. Similarly, the stem **47** has the flared ends **50** and **51**; the flared ends having the conical-like shaped portions situated next to the faces of the bores **44** and **45** on the valve body **41** so that the flared ends may be seated therein. The bores **52** and **53** connect the bores **44** and **45** with the bores **26** and **27** in the movable cylinder block portion **21**, as is illustrated at FIGURE 2. As can be appreciated from the drawing

figures, the main chamber, containing the energized working substance, can be connected, in accordance with the movement of the stems 46 and 47, to either of the bores 26 or 27 in the movable cylinder block portion 21. Similarly, in accordance with the movement of the stems 46 and 47, the energized working substance may be exhausted from either of the bores 26 or 27. Advantageously, the working substance may be hydraulic fluid, compressed air or hot gases.

It is to be understood that the valve assembly 36, hereinbefore described, is illustrative of one valve assembly that may be used. Any other valve assembly performing the same function would be suitable.

Referring, again, to FIGURE 1, a ring-like plate structure 54 is fastened by suitable means to the fixed cylinder block portion 22; the plate structure 54 providing support for the yoke member 55. Integral with the yoke member 55 is the internally threaded journal 56 which supports one part of the lead screw 25; the other end of the lead screw being coupled with the movable cylinder block 21 through the journal member 57. The lead screw 25 is rotatable about its longitudinal axis through the gears 58 and 59 by the drive motor 60 the lead screw rotating within the journals 56 and 57 in order to move the cylinder block portion 21 to the left or to the right (according to the orientation indicated at FIGURE 1) along the X—X′ axis in response to a suitable command, or error, signal introduced at the motor leads 61.

Advantageously, the actuator of this invention enables the airfoil 35 to be positioned in many position attitudes within the extremities of its greatest range of movement. An appreciation of such capability is enabled by the convenient illustration appearing at FIGURE 4 of the drawings.

For example, let it be assumed, initially, that the valve assembly 36 has been operated such that the pistons 28 and 29 are in the positions shown at FIGURE 4; i.e., piston 28 is "topped" and piston 29 is "bottomed." Accordingly, the airfoil 35, attached to shaft 33 by the coupling member 62 (FIGURE 3), is displaced from the X—X′ axis by an angle θ.

Assume, now, that the motor-driven lead screw 25 advances the movable cylinder block portion 21 through the distance Δs from position A to position B in the direction indicated by the arrow shown at FIGURE 4. The pistons 28 and 29 will move in opposite directions. The piston 28 moves toward the poppet valve side of the cylinder block 21. The piston 29 moves away from the poppet valve side. As the piston 28 moves, it compresses and thereby further increases the pressure on the energized working substance trapped in the bore 26. The pressure increases until the valve stem 46 is unseated thereby relieving the pressure by exhausting a portion of the working substance through the bore 44 in the valve body 41. When the pressure has decreased sufficiently, the stem 46 is again seated thereby trapping the remainder of the working substance in the bore 26 whereby the piston 28 is "locked" into position; the movement of the piston rods 30 and 31 causing the crossbar 32 to assume a different position attitude whereby the airfoil 35 is moved through a smaller angle $\theta 1$. Further details about the operation of the poppet valve are disclosed in the Avery patent application hereinbefore identified.

In order to retain the pistons 28 and 29 in their respective bores, the retaining rings 63 are provided as shown in the drawings.

From the foregoing discussion, showing how the airfoil 35 can be moved through variable angular displacements, it can be appreciated that for movements of the cylinder block portion 21 through distances different than the Δs indicated correspondingly different angular displacements of the airfoil are enabled.

Although one embodiment of the invention has been described and illustrated, it will be obvious to those skilled in the art that various changes, substitutions of elements and arrangements of parts may be made without departing from the spirit and scope of the invention as is hereinafter defined in the claims.

What is claimed is:

1. An actuator, for positioning an airfoil, comprising: two pistons; two piston rods, one piston rod coupled to one piston, the other piston rod coupled to the other piston; a crossbar pivotally arranged for rotation through a finite arc length about its midpoint, one piston rod being coupled to one end of the crossbar and the other piston rod being coupled with an opposing end of the crossbar, said crossbar being adapted to be coupled to an airfoil; a cylinder block assembly including a fixed block and a movable block, the movable and fixed blocks being keyed so that the movable block may be slideably positioned relative to the fixed block, the movable block having bores therein for receiving the pistons; an energizing fluid source; valve means operable for selectively admitting energized fluid to, or exhausting it from, the bores whereby the piston rods are driven in push-pull fashion; and, means connected with the movable block for positioning it relative to the fixed block whereby the airfoil may be rotated through variable finite arc lengths.

2. In a piston-and-cylinder type actuator employing a pair of push-pull driven piston rods coupled with a fixedly pivoted common linkage member for rotating said common linkage member through a limited arc about its fixed pivot, a movable piston-receiving cylinder block, a lead screw coupled with the movable cylinder block so that rotation of the lead screw displaces said cylinder block relative to said pivot, a pair of pistons connected to said piston drive rods and received in said cylinder block for limited reciprocating motion and drive means for rotating the lead screw whereby said movable cylinder block's position is varied in relation to said fixed pivot.

3. In a piston-and-cylinder type actuator employing a pair of push-pull driven piston rods coupled with a fixedly pivoted common linkage member for rotating the common linkage member through a limited arc about its fixed pivot, a movable piston-receiving cylinder block adapted to be displaced along a path parallel to the piston rods, a pair of pistons connected to said piston drive rods and received in said cylinder block for limited reciprocating motion, and means for varying the position of the movable cylinder block in relation to said fixed pivot whereby the extremities of the arc through which said common linkage member rotates are varied.

4. In a piston-and-cylinder type actuator employing a pair of push-pull driven piston rods coupled with a fixedly pivoted common linkage member for rotating the common linkage member through a limited arc about its fixed pivot, a movable piston-receiving cylinder block adapted to be displaced along a path parallel to the piston rods, a pair of pistons connected to said piston drive rods and received in said cylinder block for limited reciprocating motion and means for varying the position of the movable cylinder block in relation to said fixed pivot.

5. In a piston-and-cylinder type actuator employing a pair of push-pull driven piston rods coupled with a linkage member which is arranged for rotation through a finite arc length about a fixed pivot, means for enabling the linkage member to be rotated through variable finite arc lengths; said means comprising: a movable piston-receiving cylinder block, adapted to be displaced along a path parallel to the piston rods, a pair of pistons connected to said piston drive rods and received in said cylinder block for limited reciprocating motion and means for varying the position of the cylinder block relative to the pivot's fixed position.

6. In a piston-and-cylinder type actuator employing a pair of push-pull driven piston rods coupled with a linkage member which is arranged for limited rotation about

a fixed pivot point, a movable piston-receiving cylinder block adapted to be displaced along a path parallel to the piston rods, a pair of pistons connected to said piston drive rods and received in said cylinder block for limited reciprocating motion and means for varying the position of the cylinder block relative to the fixed pivot point whereby the rotation limits of the linkage member are varied.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,125,000 March 17, 1964

Peter G. Reuter

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 4, lines 19 and 20, for "energizing" read -- energized --.

Signed and sealed this 12th day of January 1965.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents