No. 2311642

THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

Whereas CARL J. CRANE, GEORGE V. HOLLOMAN, and RAYMOND K. STOUT, of Dayton, Ohio,

PRESENTED TO THE Commissioner of Patents A PETITION PRAYING FOR THE GRANT OF LETTERS PATENT FOR AN ALLEGED NEW AND USEFUL IMPROVEMENT IN

ELECTRIC THROTTLE ENGINES,

A DESCRIPTION OF WHICH INVENTION IS CONTAINED IN THE SPECIFICATION OF WHICH A COPY IS HEREUNTO ANNEXED AND MADE A PART HEREOF, AND COMPLIED WITH THE VARIOUS REQUIREMENTS OF LAW IN SUCH CASES MADE AND PROVIDED, AND

Whereas UPON DUE EXAMINATION MADE THE SAID CLAIMANT s are ADJUDGED TO BE JUSTLY ENTITLED TO A PATENT UNDER THE LAW.

NOW THEREFORE THESE Letters Patent ARE TO GRANT UNTO THE SAID

Carl J. Crane, George V. Holloman and Raymond K. Stout, their heirs OR ASSIGNS

FOR THE TERM OF SEVENTEEN YEARS FROM THE DATE OF THIS GRANT

THE EXCLUSIVE RIGHT TO MAKE, USE AND VEND THE SAID INVENTION THROUGHOUT THE UNITED STATES AND THE TERRITORIES THEREOF. Provided, however, that the said invention may be manufactured and used by or for the Government for governmental purposes without the payment of any royalty thereon.

In testimony whereof I have hereunto set my hand and caused the seal of the Patent Office to be affixed at the City of Washington this twenty-third day of February, in the year of our Lord one thousand nine hundred and forty-three, and of the Independence of the United States of America the one hundred and sixty-seventh.

Attest:

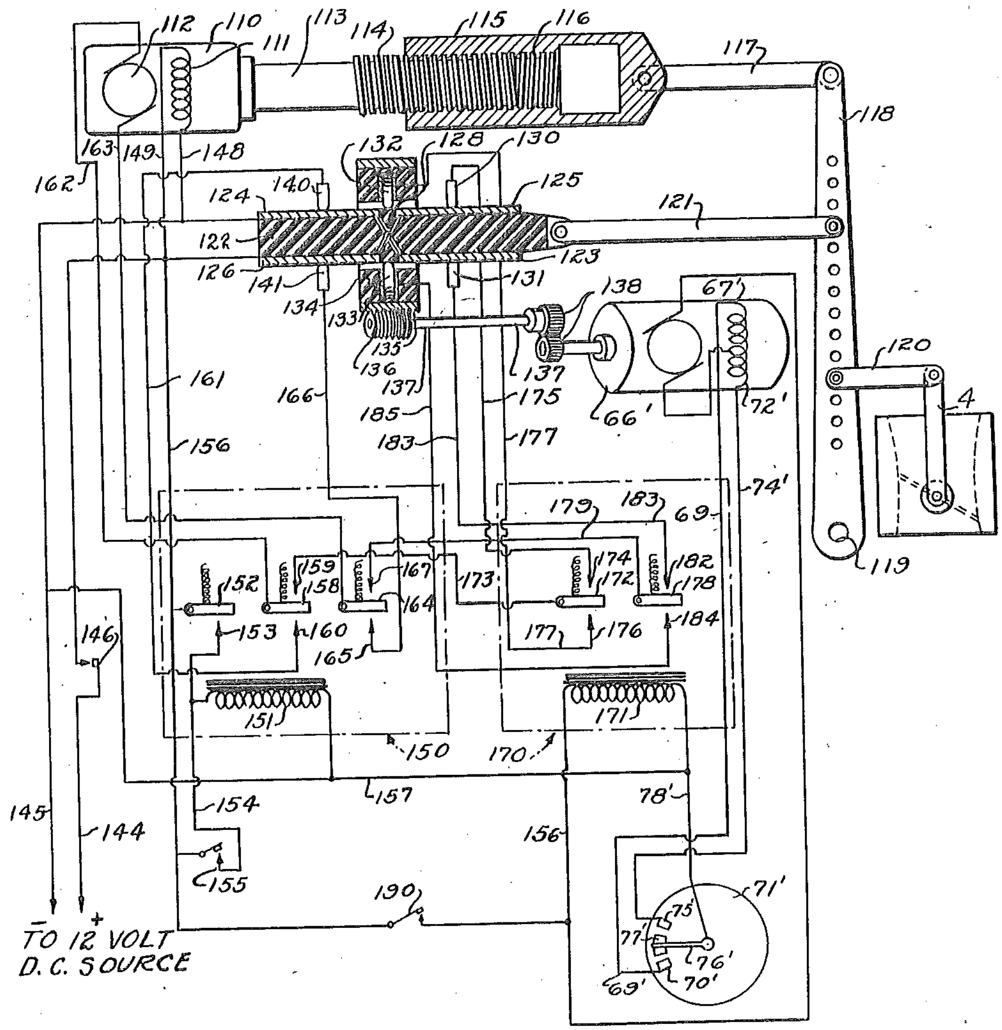
E. L. Reynolds
Law Examiner.

Conway P. Coe
Commissioner of Patents.

ELECTRIC THROTTLE ENGINE

Filed July 31, 1940 5 Sheets-Sheet 5

FIG. 7.



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Feb. 23, 1943. C. J. CRANE ET AL 2,311,642

ELECTRIC THROTTLE ENGINE

Filed July 31, 1940 5 Sheets-Sheet 4

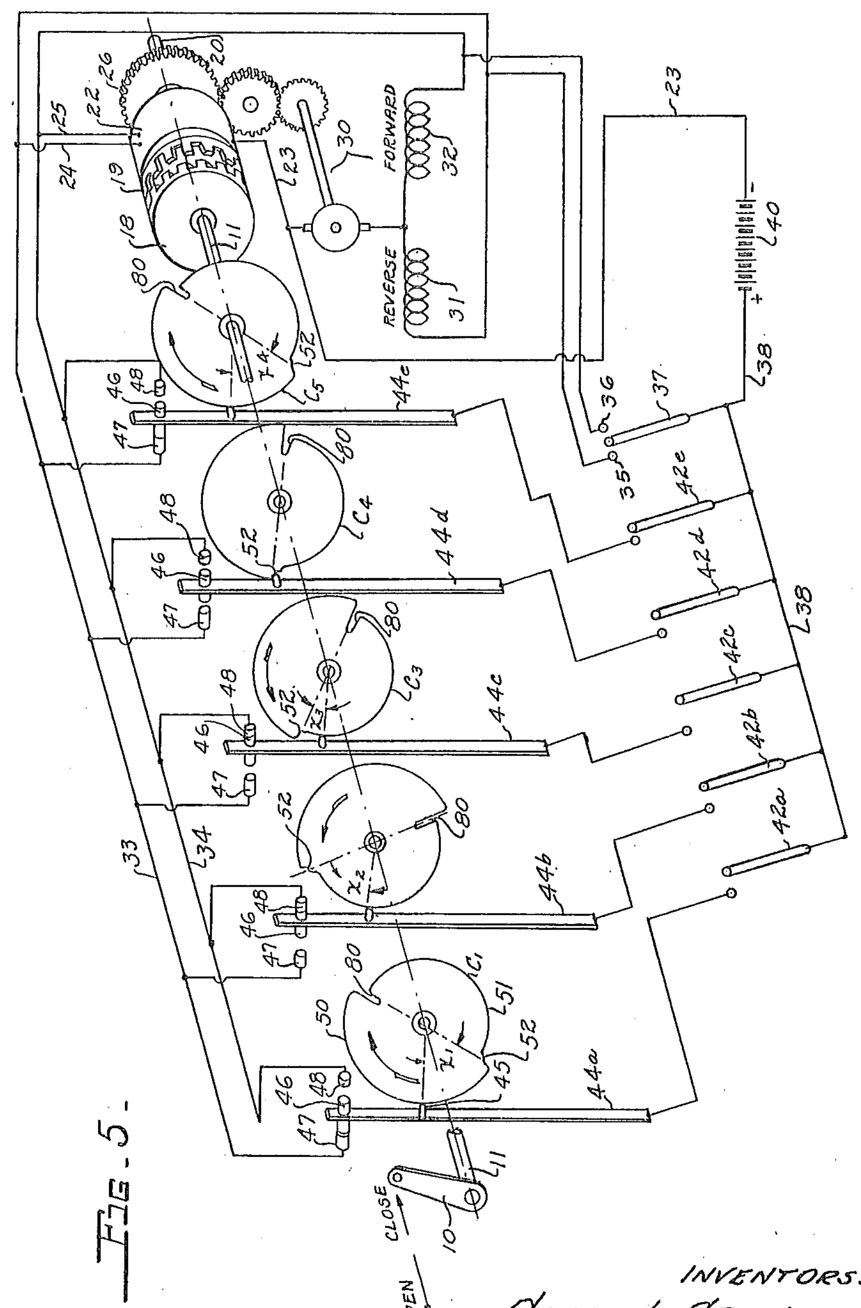

FIG. 5.

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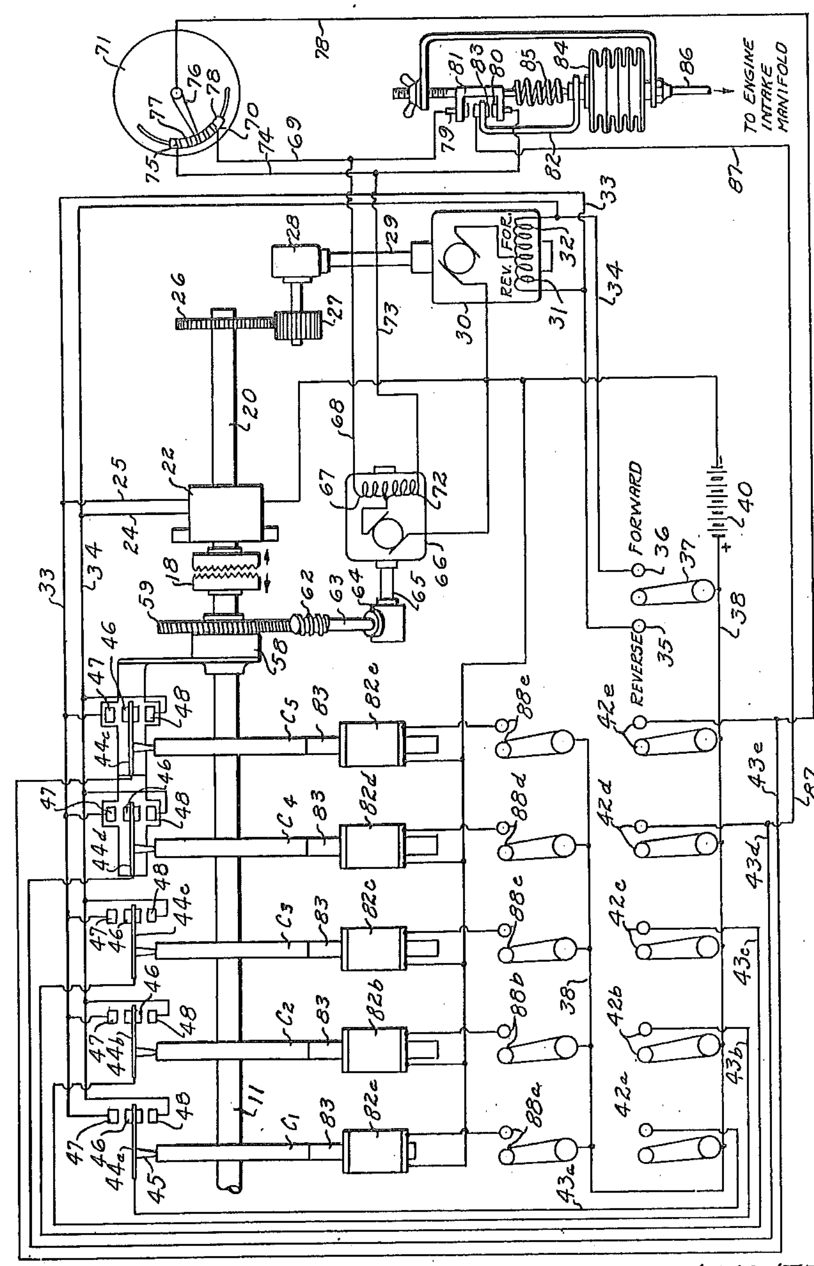
ELECTRIC THROTTLE ENGINE

Filed July 31, 1940 5 Sheets-Sheet 3



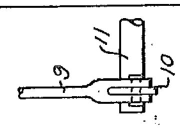


FIG. 4.

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ELECTRIC THROTTLE ENGINE

Filed July 31, 1940 5 Sheets-Sheet 2

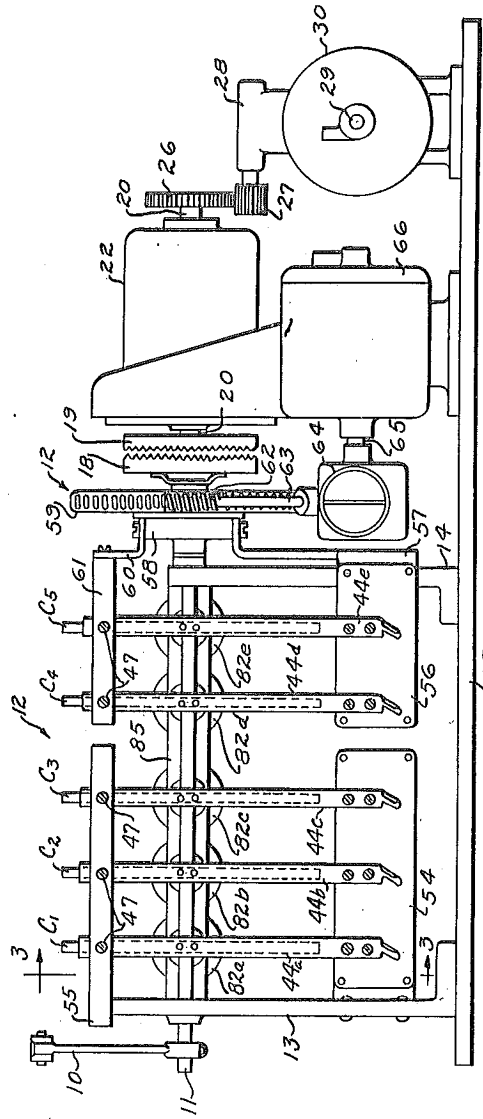

FIG. 2

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ELECTRIC THROTTLE ENGINE

Filed July 31, 1940 5 Sheets-Sheet 1

FIG. 1.

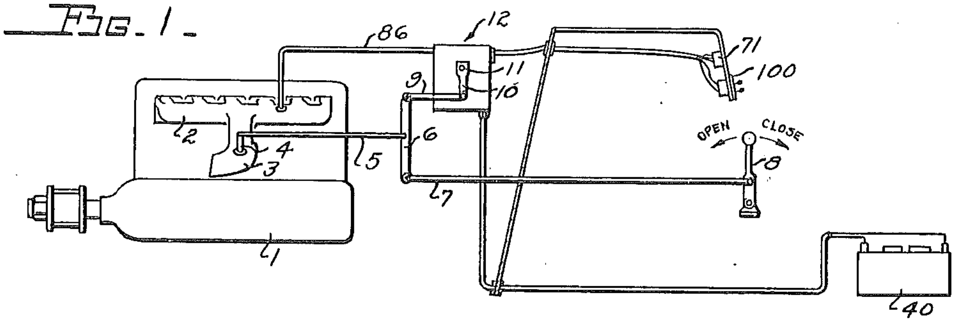


FIG. 3.

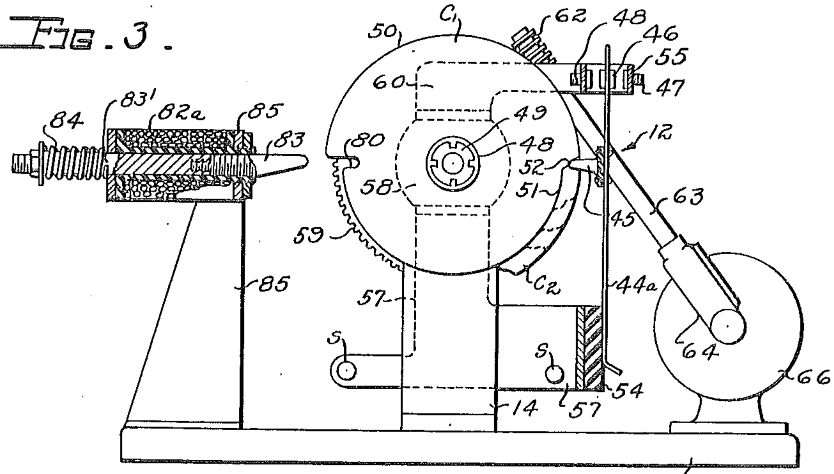
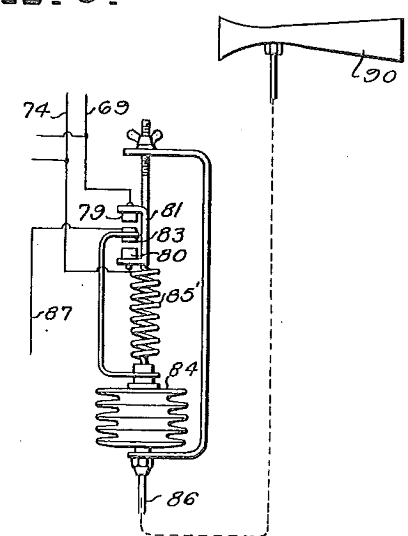


FIG. 6.



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Patented Feb. 23, 1943 2,311,642

UNITED STATES PATENT OFFICE

2,311,642

ELECTRIC THROTTLE ENGINE

Carl J. Crane, George V. Holloman, and Raymond K. Stout, Dayton, Ohio

Application July 31, 1940, Serial No. 348,720

12 Claims. (Cl. 244—76)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

The invention described herein may be manufactured and used by or for the Government for governmental purposes, without the payment to us of any royalty thereon.

This invention relates to a control system for regulating the flight conditions of an aircraft in a vertical plane such as rate of climb, rate of descent and constant airspeed at a particular altitude by regulation of the output of the power plant, and more particularly relates to a novel electric servomotor device of the type commonly known in the art as a throttle engine, for automatically setting the aircraft engine throttle in certain predetermined positions and for making a vernier, or as hereinafter termed a micrometric adjustment of the engine throttle about one or more of the predetermined throttle positions in accordance with variation in flight conditions of the aircraft, such conditions being, for example, variation in the rate of climb or descent of the aircraft from a predetermined value, variation in the horsepower output of the engine, measured, for example, by change in the intake manifold pressure or by variation in the velocity of the aircraft from a predetermined value, measured, for example, by a Venturi tube.

Devices of the type described have a general ultility in replacing the conventional manual throttle control, but in particular have been found to be practically a necessity in carrying out automatic instrument landings in accordance with an improved form of the Army Air Corps blind landing system, fully disclosed in application Serial No. 287,310, filed July 29, 1939, entitled "Aircraft—Automatic take-off flight and landing," in the names of Carl J. Crane, George V. Holloman, Raymond K. Stout, and Constantin D. Barbulesco.

The device according to the invention comprises an electric motor connected through a clutch to drive a shaft which through suitable linkage actuates the engine throttle valve. The motor-driven shaft also actuates a series of cams which control contact switches, which in turn respectively control the motor-energizing circuit and selectively serve to de-energize the electric motor in predetermined throttle positions. The predetermined throttle positions are selected by closing a switch associated with a respective cam-actuated switch. A servomotor of the type described is not new per se, being of a type used in the remote tuning of a radio set, as evidenced by United States Patent No. 2,055,363 granted to Winfred T. Powell. A novel feataure of the device, in accordance with the invention, however, is the provision of a means to micrometrically adjust the throttle about one or more of the predetermined throttle settings, the micrometric adjustment being effected by shifting the cam-actuated contact switch assembly associated with a particular cam, relative to the cam by an electric motor controlled by a rate-of-climb-responsive means, an engine intake manifold-pressure-responsive means, or by a means responsive to variation in the air speed of the associated aircraft. By means of these automatic micrometric adjustment features, the air speed of the aircraft may be kept at a substantially constant value during an approach to the landing field and, during the glide for a landing, may be kept descending at a constant rate as determined by the rate-of-climb-responsive means, which, of course, is understood in the art to include rate of climb or descent.

A further novel feature of the invention is the provision of a means for setting the cams in positions corresponding to the desired engine speeds during flight, the setting means being controlled from a point remote from the throttle engine. The novel setting means permits the throttle engine to be placed in the engine compartment adjacent the engine throttle valve and the cams to be adjusted under flight conditions from the pilot's cockpit.

A further novel feature of the invention is the provision of a clutch means operative to effect throttle adjustment to any of the selected predetermined positions or to micrometrically adjust the throttle, but disconnecting the electric driving motor upon the correct adjustment being made, thus preventing any overrunning of the electric driving motor from affecting the adjusted position of the throttle.

The principal object of the invention is the provision in an aircraft power plant control, of a power means to set the engine power-controlling throttle in any one of a plurality of predetermed positions and to micrometrically adjust the throttle about at least one of said predetermined positions.

A further object of the invention is the provision in a device of the character described, of a means to selectively control the micrometric means in accordance with a condition of aircraft flight, such a condition being engine power variation, variation in vertical velocity of the aircraft, or variation in the air speed of the associated aircraft.

A further object of the invention is the provision of an electric servomotor for controlling an aircraft engine throttle, or the control surface of an aircraft, of a type such that it may be operated to place the engine throttle, or the control surface, in any one of a plurality of predetermined positions, and in one of said positions to be always returned to the said one position after any displacement due to sudden jars or shocks.

Other objects of the invention not specifically enumerated above will become apparent to those skilled in the art by reference to the specification and the appended drawings, in which:

Figure 1 is a side elevation showing the association of the electric throttle engine with the motor of an aircraft;

Figure 2 is a front elevation of the throttle engine;

Figure 3 is a view partly in section taken on line 3—3 of Figure 2;

Figure 4 is a schematic diagram showing the electrical circuit arrangement;

Figure 5 is a schematic view illustrating the operation of the cam control of the servomotor;

Figure 6 illustrates a modified arrangement of a portion of the device of Figure 4, to be responsive to variation in velocity of the associated aircraft;

Figure 7 is a diagrammatic showing of a modified form of throttle engine having a self-locking feature.

Referring to Figure 1, the reference numeral 1 represents a conventional aircraft engine having an intake manifold 2, provided with a carburetor 3, having a conventional throttle-controlling element 4. The throttle-controlling element 4 is pivotally connected to a lever 5 which is centrally pivoted on a floating lever 6, which is connected at its lower end to a manual control rod 7, actuated by a manual throttle control 8. At its upper end, the floating lever 6 is pivotally connected to one end of a lever 9, which is pivotally connected at its other end to an arm 10 fixed on a shaft 11 of an electric throttle engine, generally indicated by the reference numeral 12. The throttle engine 12 is adapted to be energized by aircraft storage battery 40 and is also operatively connected to a rate-of-climb-responsive device 71, a switch panel—generally indicated by the reference numeral 100, and an intake manifold pressure conduit 86, all of which function in a manner hereinafter to be more particularly described. It will be seen that the throttle-control element 4 may be manually actuated by means of the throttle control 8, or may be automatically actuated by the throttle engine 12. When it is desired to utilize the automatic control, the throttle control arm 8 is moved to the closed position, and the throttle engine, through link 9 and pivoted lever 6, may then actuate the throttle-control element 4 independently of the manual control lever 8.

Referring now to Figures 2 and 3, the construction of the throttle engine 12 will now be described. The throttle engine 12, comprises a base 15 having vertical supports 13 and 14 mounted thereon, which supports serve as journals for a shaft 11 having the arm 10 secured at the outer end thereof. At its inner end the shaft 11 is provided with a dog clutch element 18 which is rigidly secured thereto and rotatable therewith. A cooperating dog clutch element 19, is mounted on the inner end of the shaft 20 coaxial with the shaft 11, and the shaft 20 is adapted to be reciprocated by a conventional magnetic solenoid 22 so as to engage or disengage the dog clutch elements 18 and 19, upon the magnetic solenoid 22 being energized and/or de-energized, respectively. At its outer end the shaft 20 is provided with a gear 26 which is adapted to mesh with an elongated pinion gear 27 driven by a speed-reducing gear 28 which, in turn, is driven by the armature shaft 29 of a reversible direct current motor 30. It will thus be seen that the motor 30 may drive the throttle engine shaft 11 in either direction, upon the clutch elements 18 and 19 being engaged, thus causing the arm 10 to actuate the throttle element 4 of Figure 1, as hereinbefore described with reference to Figure 1. A plurality of cams C_1, C_2, C_3, C_4, and C_5, are respectively frictionally mounted on the shaft 11 between the vertical supports 13 and 14. Each of these cams is respectively adapted to cooperate with a spring contact member *44a*, *44b*, *44c*, *44d*, and *44e*. Each of the contact arms *44a*, etc., is provided with a cam follower 45 which is yieldingly urged into contact with its associated cam. Each respective cam is provided at its central portion with an enlarged hub 48 having a bushing 49 of rubber, or other suitable friction material, keyed therein. The friction bushing 49 serves to maintain each respective cam in a fixed angular relation with respect to the shaft 11, but permits the cams to be angularly adjusted with respect to the shaft 11 in a manner hereinafter more particularly described. Each cam is provided with a raised arcuate section 50 and a depressed arcuate section 51, the two arcuate sections being joined by a sloping section having a neutral point 52 midway between the sections 50 and 51. Each of the flexible contact arms *44a*, *44b*, etc., has mounted thereon adjacent the outer end, a double contact 46 which is adapted to contact either a front contact 47 or a rear contact 48 associated therewith. It will be seen by inspection of Figure 3 that when, for example cam C_1 is rotated so as to bring the raised arcuate cam section 50 into contact with the follower 45, contact 46 will engage the front contact 47 associated therewith; while if the cam follower 45 engages the depressed cam section 51, the yielding contact strip 44 will urge the contact 46 into engagement with the rear contact 48. When the cam follower 45 engages the neutral cam section 52, the double contact 46 will then be spaced midway between the contacts 47 and 48 and out of engagement with either of these contacts. The spring contact members *44a*, *44b*, and *44c*, respectively, are mounted on a block of insulating material 54 secured by a suitable stationary mounting to the vertical support 13. The front and rear contacts 47 and 48, respectively, which cooperate with the respective cams C_1, C_2, and C_3, are each supported on an insulated block 55, also suitably supported by the vertical support 13. The flexible contact members *44d* and *44e* are each mounted adjacent their lower ends on a block 56 of insulating material carried by an arm 57 secured to a hub member 58 which is freely rotatably mounted on the shaft 11. The front and rear contact members 47 and 48, which cooperate with cams C_4 and C_5, are each carried by an insulating member 61 similar to the member 55, but the insulating member 61 is mounted on an arm 60 which is also secured to the hub member 58. It will be seen that as the hub member 58 is rotated about the axis of the shaft 11, contact strips *44d* and *44e*, and their associated cam followers 45 and contacts 47 and 48 will also be rotated about the axis of shaft 11. The hub member 58 is in frictional engagement with the side face of a worm gear 59, also freely rotatably mounted on the shaft 11. The worm gear 59 is adapted to be driven by a worm 62 mounted on the end of a shaft 63, which is driven by a speed-reducing gear 64 from the armature shaft 65 of a reversible direct current motor 66. It is thus seen that motor 66 may rotate the contact assembly associated with the cams C_4 and C_5 about the axis of shaft 11 in either direction of rotation.

As seen in Figure 3, the cams C_1, C_2, etc., are each provided with a slot 80 which is located diametrically opposite the neutral point 52 on each cam. A solenoid coil 82*a*, 82*b*, etc., is associated with each respective cam. The solenoid coils are provided with a plunger 83 which is formed of a nonferrous metal, such as brass or aluminum, and threaded into a soft iron plunger 83′ which is surrounded by the solenoid windings. The plunger 83′ is loaded by means of a spring 84. Whenever a respective solenoid coil 82*a*, 82*b*, etc., is energized, the plunger portion 83 engages its associated cam and eventually will enter the slot 80 upon rotation of the associated cam and lock the cam in a position such that the cam follower 45 is in contact with the cam at the neutral portion 52, with the double contact 46 out of engagement with either of contacts 47 and 48.

The operating circuit for the throttle engine is illustrated in Figure 4 and, referring to this figure, it is seen that the driving motor 30 is provided with a split field having a reverse winding 31 and a forward winding 32. The forward winding 32 is connected by means of a conductor 34 in parallel with each of the back contacts 48 associated with the respective cams C_1, C_2, C_3, C_4, and C_5. The reverse winding 31 is connected by means of a conductor 33 with the forward contacts 47, respectively associated with the responsive cams C_1, C_2, C_3, C_4, and C_5. The clutch-actuating solenoid 22 is of the double winding type, having one winding connected to the conductor 34 by means of a conductor 24 and having the other winding connected to the conductor 33 by means of a lead 25. The third lead 23 connects each of the double windings of the solenoid 22 to the negative terminal of a battery 40. The positive terminal of the battery is connected, by a conductor 38, in parallel with each of a series of switches 42*a*, 42*b*, 42*c*, 42*d*, and 42*e*, each respectively connected by means of leads 43*a*, 43*b*, 43*c*, 43*d*, and 43*e* with the flexible contact members 44*a*, 44*b*, etc. It will thus be seen that upon closing any one of the switches 42*a*, 42*b*, etc., and having the double contact 46 of a respective cam in contact with either the front contact 47 or the rear contact 48 associated therewith, an electrical circuit will be established connecting the clutch-actuated solenoid 22 and either the forward or reverse field winding of the motor 30 with the battery 40, the armature of the motor 30 being connected to the negative terminal of the battery 40 by means of the conductor 23. A switch 37 also connected to the conductor 38 is adapted to cooperate with a pair of contacts 35 and 36 to manually connect either the reverse winding 31 or the forward winding 32 of the motor 30 directly with the battery 40 for a cam-setting operation hereinafter described.

The solenoid coils 82*a*, 82*b*, 82*c*, etc., are each connected in series with a respective switch 88*a*, 88*b*, 88*c*, etc., which switches are connected in parallel with the conductor 38. The other terminals of the respective solenoid coils 82*a*, 82*b*, 82*c*, etc., are each connected in parallel to the conductor 23. It is thus seen that upon closing any one of the switches 88*a*, 88*b*, etc., the respective solenoid coil 82*a*, 82*b*, etc., will be energized, causing the associated plunger 83 to lock its respective cam C_1, C_2, etc. By energizing a respective solenoid and simultaneously causing the motor 30 to be rotated in either the forward or reverse direction by actuating switch 37 in the proper sense, the cam can finally be brought to a position such that the associated solenoid plunger 83 will lock the cam. The motor 30 can then be continued in operation until the throttle setting shaft 11 has moved to a position which will set the engine throttle at a desired point corresponding to one of the previously noted flight conditions. This adjustment can be made because of the friction connection 49 of each respective cam to the shaft 11, previously described, which allows the shaft 11 to be driven while a cam is held locked. By means of this operation, each respective cam may be so set that the neutral point 52 (see Figure 3) will be opposite the corresponding cam follower 45, leaving the associated double contact 46 in the neutral position out of engagement with either contact 47 or 48. The solenoid switches 88*a*, 88*b*, 88*c*, etc., are adapted to be mounted on the panel 100 at a point remote from the position of the throttle engine 12, and yet permitting the cams to be set in the proper position during actual flight of the airplane.

As previously described with reference to Figures 2 and 3, it is noted that the reversible motor 66 is adapted to rotate the contact assembly associated with the cams C_4, and C_5 about the axis of the shaft 11. This rotation of the contact assembly is hereinafter termed a micrometric adjustment, since actual rotation of the contacts is intended to be only a very small amount. The motor 66 is provided with a split field winding having the coils 67 and 72, respectively. The winding 67 is connected by means of a lead 68 to a conductor 69 which, in turn, is connected to a contact 70 carried by a movable contact carrier 78 associated with a rate-of-climb-responsive device 71. The other field winding 72 of the motor 66 is connected by means of a conductor 74 to a second contact 75 also carried by the contact carrier 78. The armature of motor 66 is connected to the negative terminal of the battery 40 through the medium of conductor 33. The rate-of-climb-responsive device 71 is provided with a pointer 76 which carries a double contact 77, arranged between the contacts 75 and 78 and is adapted to remain in a neutral position out of engagement by a predetermined small clearance with either of the contacts 70 or 75, upon a predetermined value of rate of climb, or descent being maintained. The pointer 76 is electrically connected by means of a conductor 78 to the contact of the switch 42*e*. When the switch 42*a* is closed, it is thus seen that an electrical circuit may be established from battery 40 through conductor 38 and switch 42*e*, to conductor 78, pointer 76, double contact 78, either of contacts 70 or 75, and either of field coils 67 or 72 through the armature of motor 66 and conductor 23 to battery 40 to thereby energize the motor 66. The motor 66 then shifts the contact strip 44*e* and its associated cam follower 45 relative to cam C_5, so that the cam follower engages one of cam sections 50 or 51, thus causing contact 46 to engage one of contacts 47 or 48 to thereby energize the clutch actuating solenoid

22 and the electric motor 30. The electric motor 30 then drives the shaft 11 in a direction such as to actuate the engine throttle control element 4 (Figure 1) to restore the rate of ascent or descent to the proper predetermined value, at which time the pointer 76 will move to the neutral position, de-energizing motor 66 and the cam follower 45 will then be positioned on the neutral section 52 of cam C_5, causing the clutch actuating solenoid 22 and motor 30 to each become de-energized leaving the shaft 11 in the adjusted position.

The conductors 74 and 69 are also connected in parallel to a pair of contacts 79 and 80, respectively, carried by a support 81 associated with a manifold-pressure-responsive means. The contact carrier 81 is adapted to be actually shifted by means of a threaded rod and thumb screw, as shown in Figure 4, against the resistance of a coil spring 85 connected at one end thereto and having its other end connected to a pressure-responsive bellows 84. The bellows 84 is adapted to be connected by means of a conduit 86 to the intake manifold 2 of the engine 1, as previously noted with respect to Figure 1. The bellows 84 carries a contact support 82 upon which is mounted a double contact 83 spaced between and adapted to engage either of the contacts 79 or 80, and the double contact 83 is electrically connected by means of a conductor 87 to the contact of switch 42*d*. The tension of spring 85 is so adjusted that the contact 83 is normally out of engagement with either contact 79 or contact 80, upon a predetermined manifold pressure representing a desired engine horsepower output being obtained. Upon closure of switch 42*d*, if the engine horsepower should vary due to flight load conditions, the contact 83 can engage either contact 79 or contact 80, to cause the motor 66 to make a micrometric adjustment of the contact assembly associated with cam C_4 to cause motor 30 to actuate the throttle adjusting shaft 11 to restore the engine power output to a value sufficient to carry the new load and thus maintain the engine manifold pressure substantially constant. The operation of the motor 66 is the same as previously described with reference to the rate of climb responsive control.

Operation

Cam setting

As described above with reference to Figure 4, it is seen that the respective cams C_1, C_2, C_3, etc., can be set in a desired angular relation with respect to shaft 11, corresponding to desired engine throttle positions. Each of the cams C_1, C_2, C_3, C_4, and C_5 correspond to certain predetermined engine power output conditions, such as, for example, throttle-off condition, take-off condition, cruising condition, slow cruising condition, and gliding condition. The cams C_1, C_2, etc., are set so that their neutral positions correspond to the requisite throttle positions for each of the above mentioned flight conditions in the manner previously described. This setting operation must be accomplished during flight, because of the fact that the engine revolutions on the ground for a given throttle setting will differ from the engine revolutions during flight, for the same throttle setting. The setting is accomplished by closing one of the locking solenoid switches 88*a*, 88*b*, etc. and manually actuating switch 37 to cause the electric servomotor 30 to drive shaft 11 in a direction to set the engine throttle for the desired flight condition. The solenoid 82*a*, 82*b*, 82*c*, etc. associated with the selected switch 88*a*, etc., will cause the selected cam to be locked as previously described and the motor 30 is continued to be manually operated until the engine throttle is in the desired position, at which time switch 37 is then opened stopping operation of motor 30. The selected cam will then be in a position such that its neutral point 52 will be opposite the corresponding follower 45 and the corresponding contact 46 will be out of engagement with its corresponding associated contacts 47 and 48. The selected locking solenoid switch 88*a*, etc. is then opened and is not thereafter employed until a resetting is required. Each of the cams is set in a similar manner and after being properly set thereafter serves to control the servomotor 30, so that the servomotor always adjusts the engine throttle to the predetermined position determined in the setting operation. This remote control for setting the respective throttle-controlling cams is deemed a novel feature of the invention, since it is substantially impossible to make the proper adjustment of a number of the cams on the ground, and manual adjustment of the cams is precluded in flight due to the location of the throttle engine in the engine compartment, which in most aircraft is not accessible during flight.

Servomotor operation

The operation of the electric servomotor for setting the throttle shaft 11 of the throttle engine 12 in any one of its predetermined positions is best understood by reference to the schematic diagram illustrated in Figure 5. As seen in Figure 5, each of the cams C_1, C_2, C_3, etc., has a definite angular position indicated by the reference characters X_1, X_2, X_3, etc., with respect to the shaft 11; and it will be seen that all of the flexible contact members 44*a*, 44*b*, 44*c*, etc., will be in contact with either the front contacts 47 or the rear contacts 48, unless one of the cam followers 45 is located on the central section 52 of its associated cam. If then any one of the switches 42*a*, 42*b*, etc., be closed, a circuit will be established from battery 40 to the respective switch, for example, 42*a*, double contact 46, front contact 47, conductor 33, reverse winding 31 of motor 30 through the armature winding thereof to conductor 23 and to the negative terminal of the battery 40. Simultaneously, a circuit will be completed from the battery 40 through conductor 33, conductor 25, through one of the windings of the clutch-actuating solenoid 22, to cause the clutch elements 18 and 19 to be drivingly engaged. The motor 30 may then rotate in a direction such as to rotate the cam C_1 as indicated by the arrow in Figure 5. The throttle shaft 11 will then rotate in the throttle-closing direction until the neutral point 52 of the cam C_1 is directly opposite the cam follower 45, at which time engagement between double contact 46 and front contact 47 will be broken. Interruption of this contact will de-energize conductor 33 causing motor 30 and clutch-actuating solenoid 22 to be simultaneously de-energized, the clutch elements 18 and 19 being disengaged through the medium of a spring (not shown) within the solenoid 22, tending to cause axial movement of the shaft 20 to the right. As seen in Figure 4, the elongated pinion 27 allows gear 26 to partake of the axial movement of the shaft 20 without disestablishment of the driving relation between the motor 30 and the shaft 20. The throttle will then be in the "off" or "closed" position. If, for example, the switch 42*c* should now be closed and switch 42*a* opened, the double contact 46 of the contact member 44*c* will be in engagement with its associated contact 48, causing a circuit to be established from battery 40, conductor 38, switch 42*c*, contacts 46 and 48 to conductor 34 and the forward winding 32 of motor 30, causing motor 30 to be operated in the direction as indicated by the arrow in Figure 5, to cause the shaft 11 to move the throttle-control arm 10 in the opening direction. The shaft 11 will continue to open the engine throttle until the engine speed is at a value corresponding to the desired cruising engine speed, at which time the follower 45 will be opposite the neutral point of the cam C_3, interrupting the supply of energy to motor 30 and clutch actuator 22, which is now receiving power through the conductor 24. The shaft 11 will thus be de-clutched from driving relation with the motor 30. In a similar manner, by closing any one of the switches 42*a*, 42*b*, 42*c*, etc., the shaft 11 can be set in any one of the predetermined throttle-setting positions for which each respective cam has been previously set. Any number of cams more or less than the five here illustrated may be used. The structure and operation of the servomotor per se is old in the prior art, as evidenced by the previously noted patent to Powell, and the novel feature of micrometric adjustment will now be described:

Micrometric adjustment

In the course of accomplishing an instrument landing in accordance with the well-known Army aircraft system and modified forms thereof, it is absolutely essential that the velocity of the airplane be maintained at some predetermined value previous to making a final descent during a glide. The engine throttle setting corresponding to this predetermined speed is the above-entitled slow cruising position, which is controlled by the cam C_4. While the cam C_4 will position the shaft 11 and throttle-control arm 10 in a position very closely approximating the desired value, slight variations due to external conditions of flight may prevent the actual desired flight speed from being actually attained, which would thus require an additional manual adjustment of the throttle, destroying much of the utility of the throttle engine. In order to overcome this difficulty and to obviate the necessity of making manual adjustments, the micrometric adjustment of the throttle shaft 11 previously described is employed. If we consider that the shaft 11 and associated cam C_4 are in the position corresponding to the desired slow cruising flight condition switch 42*d* will be closed, the double contact 46 associated with the cam C_4 will be out of engagement with either of its associated contacts 47 and 48, and motor 30 and clutch-actuating solenoid 22 will both be deenergized. If, however, the velocity of the airplane is at some value other than the predetermined value, the engine horsepower output will vary from the predetermined horsepower output as measured by the predetermined intake manifold pressure. Any variation in the intake manifold pressure from the predetermined value will cause the contact 83 to engage either contact 79 or contact 80 to energize the motor 66 in the manner previously described. Motor 66 will then rotate in a direction such that worm 62 will rotate worm gear 59 to frictionally drive the hub 58 and the contact-carrying arms 57 and 60 (Fig. 2) to cause the cam follower 45 associated with the cam C_4 to be shifted off the neutral position 52 of the cam. The shifting of the follower 45 will cause the contacts 46 to engage either contact 47 or contact 48 to energize the clutch-actuating solenoid 22 and motor 30 to effect a throttle-adjusting rotation of shaft 11 of such a value as to restore intake manifold pressure to the predetermined value, thus interrupting engagement between contact 83 and one of contacts 79 or 80, to thereby de-energize motor 66 and prevent further adjustment of the cam follower associated with the cam C_4. It is to be understood that the motor 66 is so geared to gear 59 that the gear 59 will rotate at a very slow speed, thus giving ample time for engine conditions to be restored to the proper value before any appreciable adjustment of the contact arms 57 and 60 has been made. However, in the event of motor 66 making a large adjustment, stops S on the contact carrier 57 (see Fig. 3) will prevent further adjustment of the contacts, and the frictional drive between the hub 58 and the gear 59 will permit the gear to slip relative to the hub without stalling motor 66.

After a descent is started during a blind landing in accordance with the above-noted system, it is necessary that a predetermined rate of descent be adhered to, which heretofore required a close manual adjustment of the throttle during the course of the descent. In order to alleviate the necessity for manual adjustment during the glide, the throttle may be first set approximately in the proper position for a glide by closing the switch 42*e*, causing cam C_5 to effect a setting of shaft 11 in the throttle position corresponding to the glide condition. If, however, the rate of descent of the airplane should vary from the predetermined desired value, the rate-of-climb-responsive device 71 may also effect a micrometric adjustment of the throttle shaft 11 in the manner previously described with reference to Figure 4. It is seen that the rate-of-climb-responsive mechanism is operative to effect the energization of motor 66 only when the switch 42*e* is closed, and since only one of the switches 42*a* to 42*e*, inclusive, are ever closed at any one time, the possibility of the pressure-responsive device 84 and the rate-of-climb device 71 being operative simultaneously is thus eliminated. It is thus seen that by means of the above described device, the electric throttle engine may, by actuation of a selected one of the switches 42*a*, 42*b*, etc., position the throttle control element 4 (Fig. 1) of the engine 1 in any one of a plurality of predetermined positions corresponding to definite flight conditions and that in at least two of the selected positions, micrometric adjustment of the throttle may be obtained to maintain the flight conditions within desired narrow limits without requiring any manual control on the part of the pilot. The switches 42*a*, 42*b*, 42*c*, etc., may be manually actuated by the pilot and mounted on the panel 100 (Fig. 1) or one or more of these switches—for example, switches 42*d* and 42*e*—may be actuated by automatic devices, for example, a marker beacon radio receiver. A switch 42*a* may be, if desired, actuated by a landing gear switch. This application, however, is not concerned with the manner in which the various throttle engine switches are actuated, and the means for actuating these switches forms no part of the present invention.

In the device illustrated in Figures 1 and 4, an engine intake manifold-pressure-responsive device has been disclosed for the purpose of micrometrically adjusting the throttle during the glide flight condition controlled by the cam C_5. If desired, however, this device may be actuated by a means responsive to variation in aircraft velocity from a predetermined value, as illustrated in Figure 6. As seen in Figure 6, the pressure-responsive device 84 is actuated by means of the conduit 86 connected to the constricted throat of a Venturi tube 90 which is adapted to be exposed to the air stream external of the aircaft. The connections of the velocity-responsive device in the circuit of Figure 4 are identical to those already illustrated in Figure 4, so that the same reference numerals have been applied. It is necessary only to replace the spring 85 of the device of Figure 4 by a spring 85′ so calibrated and tensioned that the suction created at a predetermined aircraft velocity in the throat of the Venturi tube 90 will cause the bellows 84 to just balance the load of the spring 85′. If the aircraft velocity should decrease below the predetermined value for the slow cruising condition, the suction produced by the venturi 90 in the bellows 84 will decrease and spring 85′ will contract, moving contact 83 into engagement with contact 79, thus energizing the motor 66 through the field coil 67 to operate motor 66 in such a direction as to cause a shifting of the contact follower 45 associated with the cam C_4, to cause the shaft 11 to move in the throttle-opening position. If the velocity of the aircraft should increase above the predetermined value corresponding to the slow cruising condition established by cam C_4, the suction produced in bellows 84 will increase, causing contact 83 to move downward into engagement with contact 80, causing motor 66, through the field coil 72, to be energized to cause a movement of the contacts and contact follower associated with cam C°, to effect a micrometric adjustment of shaft 11, to decrease the throttle setting, to thereby restore the airplane velocity to its predetermined value.

Each of the devices 71 and 84 is an example only for purposes of illustration and is not to be considered as actual embodiments of devices found most suitable for the intended purpose. The construction of a rate-of-climb-responsive switch and mechanism or an intake manifold-pressure-responsive switching device per se forms no part of the present invention, since other devices than those illustrated are equally well adapted for the purpose disclosed.

Figure 7 illustrates a modified form of throttle engine for controlling the throttle element 4 in a manner similar to the device of Figure 1. In this figure, parts similar to the device of Figures 1 to 5 inclusive are given the same reference numerals, except that the numerals are primed. The device as illustrated in Figure 7 comprises an electric servomotor 110 having a field winding 111 and an armature 112 which is adapted to drive a shaft 113 in either a forward or reverse direction, depending upon the arangement of the circuit of motor 110. The shaft 113 is provided with threads 114 arranged to form an elongated screw upon which is threaded a nut member 115 internally threaded as at 116. The nut 115 is connected by means of a link 117 to the upper end of a floating lever 118. The floating lever is pivotally mounted on a stationary pivot 119 at its lower end. The floating lever 118 is connected to the engine throttle-control element 4 by means of a link 120. Intermediate its ends, the floating lever 118 is connected by means of a follow-up link 121 to a contact-supporting member 122 made of any suitable insulating material. The contact-supporting member 122 is supported, by means not shown, for axial movement, and has mounted thereon four contacts 123 to 126, inclusive which are slidable relative to stationary and relatively stationary contacting brushes. The contacts are arranged in opposite pairs with insulated dead spaces 128 located therebetween. Three pairs of contacting brushes are associated with the contacts 123 to 126, inclusive, the first pair 130, 131 corresponding to the "cruising" position of the engine throttle, the second pair 132, 133 corresponding to the "glide" position of the engine throttle, and the third pair 140, 141 corresponding to the "throttle-off" position of the throttle-controlling element 4. The slidable contact members 125 and 126 are arranged diagonally on opposite sides of the contact-supporting member 122 and are electrically connected, and the slidable contacts 123 and 124 are similarly arranged and also electrically connected. The pairs of brushes 130, 131 and 140, 141 are arranged to be stationarily supported by a suitable means (not shown). The brushes 132 and 133, however, are mounted on an insulated carrier 134 having rack teeth 135 cut on the external surface thereof and adapted to mesh with a worm 136 mounted on a shaft 137 adapted to be driven by a speed-reduction gear 138, which in turn is driven in either direction by the motor 66′, for the purpose of making a micrometric adjustment similar to the device disclosed in Figures 1 to 5 inclusive. The pinion gear 136 is adapted to cause an axial movement of the contacts 132 and 133 relative to the contact-supporting member 122. The contact member 126 is adapted to be connected by means of a flexible connection (not shown) to a positive power supply conductor 144, and the contact 124 is similarly connected to a negative power supply conductor 145. The power supply conductor 144 has a switch 146 inserted in series therewith and adapted to interrupt the supply of power when desired. The field 111 of the motor 110 is permanently connected across the power supply conductors 144 and 145 by means of the conductors 148 and 149, so that the motor field is continuously energized as long as power is flowing in conductors 144 and 145. A circuit-controlling relay, generally indicated by the reference numeral 150, as shown by the dotted lines in Figure 7, is provided with an actuating solenoid coil 151, which is adapted to cooperate with each of three relay arms 152, 158 and 164, respectively. The relay arms are each normally biased by means of springs or the like, and attracted downward whenever the solenoid coil 151 is energized. The relay arm 152 is connected to the power supply conductor 144 by means of a conductor 156, and is adapted, when actuated by the relay solenoid, to engage in contact 153, which is actuated by means of a conductor 154 to one end of the solenoid coil 151 and from thence through a switch 155 to the conductor 156. The other end of the solenoid coil 151 is connected by means of a conductor 157 to the negative power supply conductor 145. It will be seen that whenever switch 155 is closed, the relay coil 151 will be energized, and that upon the relay arm 152 engaging contact 153, the relay coil 151 will be energized through a circuit independent of switch 155, which serves in a holding or locking function in a manner more particularly hereinafter described. The relay contact arm 158 is adapted, when in its normal position, to engage a contact 159, and to engage an oppositely spaced contact 160 whenever the relay coil 151 is energized. The relay arm 164 is similarly adapted to engage a contact 167 in its normal position and to engage a contact 165 when depressed by means of the coil 151. The relay arm 158 is electrically connected by means of a conductor 162 to one side of the armature 112 of motor 110, and a conductor 163 similarly connects the other side of the armature 112 to the relay arm 164. The lower relay contact 160, associated with the relay arm 158, is connected by means of a conductor 161 to the brush 140. The lower contact 165, associated with the relay arm 164, is similarly connected by means of a conductor 166 to the brush 141.

The second circuit-controlling relay, generally indicated by the refrence numeral 170, comprises a solenoid coil 171 connected at one end to the conductor 156 through the medium of a series switch 190, the other end of the solenoid coil 171 being connected to the conductor 157. It will be seen, by inspection of Figure 7, that the solenoid coil 171 is arranged in parallel with the solenoid coil 151, and can be energized at will by closing switch 190. The solenoid coil 171 is associated therewith to relay arms 172 and 178 respectively, each of which is adapted to be normally urged by a spring in one direction to engage upper contacts 174 and 182, respectively. Upon the solenoid coil 171 being energized, the relay arms are respectively drawn downward into engagement with the contacts 176 and 184, respectively. The upper contact 174 is connected by a conductor 175 to the brush 130; and the lower contact 176, associated with the relay arm 172, is connected by means of a conductor 177 to the brush 132. The upper contact 182, associated with the relay arm 178, is connected by means of a conductor 183 to the brush 131; and the lower contact 184, associated with the relay arm 178, is connected by means of a conductor 185 to the brush 133. The micrometric adjustment motor 66′, identical in all respects to the motor 66 (Fig. 4), has split field windings 67′ and 72′, respectively, connected to contacts 75′ and 70′, respectively, of a rate-of-climb-responsive device 71′, similar to the device 71 of Figure 4. The rate-of-climb-responsive pointer 76′, having the contact 77′ adapted to engage either contact 70′ or 75′ in the manner previously described with respect to the device of Figures 1 to 5, is electrically connected by means of a conductor 78′ to one end of the relay solenoid coil 171. The armature of the motor 66′ is electrically connected by means of the conductor 172 to the other terminal of the solenoid 171 of the relay 170. It will be seen by inspection of Figure 7 that whenever the relay coil 171 of the relay 170 is energized, the rate-of-climb-responsive device 71′ is adapted to cause operation of the motor 66′ in the same manner as in the device Figures 1 to 5 inclusive, the actuation of the motor 66′ causing a micrometric adjustment of the brushes 132 and 133, respectively.

OPERATION

The device disclosed in Figure 7 is intended to operate to move the engine-throttle-control element (Figure 4) into the "cruising" and "glide" and "throttle-off" positions, the first of which will now be described.

In order to cause the engine-throttle-control element 4 to be placed in "cruising" position, from the position as seen in Fig. 7, switches 155 and 190 are each open, and switch 146 is closed; and power from the positive power supply conductor 144 will then flow through contact 126 to contact 125, brush 130, conductor 175, contact 174, through relay arm 172, conductor 173, to contact 159, relay arm 158, and conductor 162 to the armature 112 of the motor 110. Current will then flow from armature 112 through conductor 163 to relay arm 164, contact 167, conductor 179, to relay arm 178, contact 182, brush 131, contacts 123 and 124 to the negative power supply conductor 145, thus completing an electrical circuit through the motor armature. Since current is continuously flowing through the field coil 111 of motor 110, the motor will begin to run in a direction such that nut 115 will be fed axially towards the right, as seen in Figure 7, opening the engine throttle, and through the medium of the floating link 118, will cause a simultaneous movement in the same direction of follow-up link 121 in the switch assembly 122 to 126, inclusive. This movement will continue until the dead spaces 128 come opposite the brushes 130 and 131, thus interrupting the electrical circuit through the motor armature and stopping the motor 110 and leaving the throttle-control element 4 in an adjusted position corresponding to the desired cruising power output of the associated engine. It will be noted that if, for any reason, the throttle should be jarred beyond the "cruising" setting, the brushes 130 and 131 would then contact the slidable contacts 124 and 126, respectively, which will reverse the flow of current through the motor armature 112 from that described above, which reversal of current will cause motor 110 to again restore the throttle to the "cruising" position. From the above description, it is apparent that whenever the switches 155 and 190 are in the open position, upon closure of the power switch 146 the motor 110 will always place the engine-throttle-control element 4 in the "cruising" position.

Operation of the servomotor to place the engine throttle element 4 from the "cruising" into the "glide" position will now be described. In order to effect this throttle setting, the switch 190 is closed—to thereby effect the energizing of the solenoid coil 171 of relay 170—either manually or automatically in response, for example, to a radio signal receiving device, as noted with respect to the device of Figures 1 to 5 inclusive. Switch 146 being closed, power will be supplied from conductor 144 to contact 126 then through brush 133, conductor 185, contact 184, and arm 178 of relay 170 which is now active. From relay arm 178 the current flows to conductor 179, contact 167, relay arm 164, and conductor 163 to the armature 112 of motor 110. The current returns from armature 112 through conductor 162 to relay arm 158 and contact 159 and thence by conductor 173 to relay arm 172 and relay contact 176 of relay 170. The current then flows by means of conductor 177 to brush 132 and contact 124 to the negative return line 145 of the power supply, thus completing the circuit. The motor 110 will then be energized to move the throttle closed until it reaches the predetermined "glide" position, simultaneously moving the insulating support 122 axially to the left until the dead spaces 128 are opposite brushes 132 and 134 as shown in Fig. 7, thereby opening the armature circuit to motor 110, de-energizing the same. The rate-of-climb-responsive device 71′, having been set for a predetermined rate of descent, will control the motor 66′ to effect a micrometric adjustment of the brushes 132 and 133 in the event that the preselected adjustment of throttle 4 is not of such a value as to maintain the proper rate of descent during a glide to effect an instrument landing. This micrometric adjustment is substantially the same as the micrometric adjustment of the device illustrated in Figure 4 in the "glide" position. It is obvious, however, that the vernier adjustment of the respective brushes could be effected by means of a manual vernier control, which could be applied equally well to more than one pair of brushes if so desired. It will be noted that regardless of the position of the brushes 132 and 133 relative to the contact assembly 122 to 126 inclusive, the current flow through the armature of the motor 112 will always be in such a direction that the motor 110 will adjust the throttle-controlling element 4 in a position such that the neutral dead spaces 128 will be opposite brushes 132 and 133 for the glide condition.

The "throttle-off" setting of throttle-control element 4 in Figure 7 from the "glide" position will now be described: In order to effect the setting of the throttle-control element 4 of the device of Figure 7 in the "off" position, the switch 146 will be closed, and switch 155—which preferably is operated automatically by the landing gear upon contact of the aircraft with the ground—will be closed, thus energizing the solenoid coil 151 of the relay 150 in the manner previously described. The relay arm 152 of the relay 150 will engage the contact 153 to energize the solenoid coil 151 independently of the switch 155, as previously described. This operation of locking relay 150 independently of the position of the switch 155 is necessary, due to the fact that in a hard landing the switch 155 may be jarred to the open position, which would render possible the jarring of the throttle to the open position without its being thereafter returned to the closed position. The locking of the solenoid coil of relay 150 is an important feature of the device shown in Figure 7 when employed for the purpose disclosed. Current from the conductor 144 will flow, for example, through contact 126, brush 141, conductor 166, to contact 165, relay arm 164 of relay 150, conductor 163, through motor armature 112. Current will return from motor armature 112 through conductor 162, through relay arm 158 of relay 150, to contact 160, conductor 161, brush 140, contact 124, to the negative power supply conductor 144. The field 111 of the motor 110 being continuously energized, the current flowing through the armature 112 will cause the motor 110 to rotate in a direction such that the throttle-control element 4 will be set in the "throttle-off" position, and the floating lever 118 will move the switch assembly 122 to 126, inclusive, axially to the left, as seen in Figure 7, to a position such that the brushes 140 and 141 are directly opposite the dead spaces 128, at which time the motor 110 will be de-energized. Once relay 150 is energized and locked by means of relay arm 152, it will remain energized until the main power supply switch 146 is opened, thus preventing any accidental opening of the throttle due to jars or jolts in landing, as previously described.

Though the operation of the throttle engine disclosed in Fig. 7 has been described in a certain sequence, by tracing the electrical circuits in the manner as previously described, it will be seen that motor 110 will always be operated to actuate the engine throttle into the selected position regardless of the instant position of the throttle. Whenever "cruising" position is selected, motor 110 will operate until the contact dead space 128 is opposite brushes 130 and 131, and similarly for the "glide" and "throttle off" positions the motor 110 will operate until the contact dead space 128 is opposite contacts 132 and 134 and contacts 140 and 141 respectively.

While the throttle engine disclosed in Figure 7 has been illustrated as applied to the control of an aircraft engine throttle element, the engine is also adapted to control other elements—for example, an aircraft or ship rudder. For such use the holding circuit for the relay 150, including relay arm 152 and associated contact 153, is eliminated; also the rate-of-climb-responsive control and vernier adjustment features illustrated in Figure 7 are eliminated. The spacing of the pairs of brushes 140—141, 132—133, and 130—131 is so arranged that the middle pair of brushes corresponds to the neutral position of the rudder and is equivalent to the operation of the device of Figure 7 in setting the throttle to the "cruise" position. Then upon energizing either of the relays 150 or 170, the servomotor 110 may effect an adjustment of the rudder to either of two angular positions on opposite sides of the neutral position. These positions may be such as to cause predetermined rates of turn in the associated aircraft.

While we have illustrated several preferred embodiments of the invention, it will be apparent to those skilled in the art that other modifications of the invention may be made, falling within the scope of the invention as defined by the appended claims.

We claim:

1. In combination an aircraft engine, a throttle control element for said engine, an electric servomotor for actuating said throttle control element into selected predetermined positions, a plurality of switches each selectively operative to energize said servomotor, a plurality of switch means each operative to de-energize said servomotor, a cam follower operatively associated with each of said last named switch means for actuation of the same, a cam associated with each cam follower and actuated by said servomotor, each of said cams being operative to actuate its associated cam follower to thereby de-energize said servomotor in a respective one of said predetermined positions and means for finely adjusting the relation of one of said cam followers with respect to its associated cam to thereby cause said servomotor to apply a proportional vernier adjustment to said engine throttle control means.

2. In combination, an aircraft engine, a throttle control element for said engine, an electric servomotor for actuating said throttle control element into selected predetermined positions, a plurality of switches each selectively operative to energize said servomotor, a plurality of switch means each operative to de-energize said servomotor, a cam follower operatively associated with each of said last named switches for actuation of the same, a cam associated with each cam follower and actuated by said servomotor to thereby de-energize said servomotor in a respective one of said predetermined positions, means for finely adjusting the relation of a plurality of said cam followers with respect to their respective associated cams to thereby cause said servomotor to apply a proportional vernier adjustment to said engine throttle control means in any one of certain of said predetermined positions.

3. In an electric servomotor of the type having a shaft adapted to be driven a predetermined amount in either direction by a reversible elec-

tric motor, electric switch means for selectively causing said servomotor to drive said shaft, individual follow-up means each including a cam and operative to selectively de-energize said electric motor upon said shaft attaining a selected predetermined position, each of said cams being frictionally mounted on said shaft to be driven thereby, locking means cooperating with each of said cams for locking each cam in a predetermined position, means for independently energizing said electric motor to run in either direction relative to a selected locked cam and remotely controlled means for selectively actuating said locking means.

4. The structure as claimed in claim 3, in which the means for locking each of said cams comprises a slot in each cam, a releasable locking detent cooperating with said slot and electrical means for causing said detent to engage said slot.

5. In a control system for regulating certain conditions of flight of an aircraft such as rate of change of altitude and level flight at a constant airspeed by regulation of the power output of the power plant thereof; comprising regulating means for varying the output of the power plant, servomotor means connected to said regulating means to actuate the same, selective control means for said servomotor means operative to cause the servomotor means to position the power output regulating means in a selected one of a plurality of predetermined positions each corresponding to a particular value of a respective one of said flight conditions, and separate power operated control means operative when said power output regulating means is positioned in a certain one of said predetermined positions to cause a vernier adjustment of the power output regulating means in response to variation in the value of the flight condition corresponding to said certain position from a predetermined value.

6. The structure as claimed in claim 5, in which the separate power operated control means includes a sensitive pressure responsive device responsive to variation in the vertical velocity of the associated airplane as measured in terms of rate of change of barometric pressure from a predetermined value.

7. The structure as claimed in claim 5, in which the separate power operated control means includes a sensitive pressure responsive device responsive to variation in the power plant intake manifold pressure from a predetermined pressure.

8. The structure as claimed in claim 5, in which the separate power operated control means includes a sensitive pressure responsive device responsive to variation in dynamic pressure of the airstream from a predetermined value corresponding to a predetermined airspeed.

9. In a control system for regulating certain conditions of flight of an aircraft such as rate of change of altitude and level flight at a constant airspeed by regulation of the power output of the power plant thereof; comprising regulating means for varying the output of the power plant, servomotor means connected to said regulating means to actuate the same, selective control means for said servomotor means operative to cause the servomotor means to position the power output regulating means in a selected one of a plurality of predetermined positions each corresponding to a particular value of a respective one of said flight conditions, and separate power operated control means for controlling said servomotor means operative when said power output regulating means is in a certain one of said predetermined positions to cause a vernier adjustment of the power output regulating means in response to variation in the value of the flight condition corresponding to said certain position from a predetermined value.

10. The structure as claimed in claim 9, in which the separate means to control the servomotor means also includes a means operative to cause the servomotor means to apply a vernier adjustment of the power output regulating means operative when the latter is in another selected one of said predetermined positions than said certain position in response to variation from a predetermined value of the value of the flight condition corresponding to last named selected position of the power output regulating means.

11. The structure as claimed in claim 9, in which the means for applying a vernier correction to said power output regulating means through said servomotor means includes a first control means operative when said power output regulating means is in said certain predetermined position to cause a vernier adjustment of said power output regulating means in response to variation in the rate of change of altitude from a predetermined value and a second control means operative when said power output regulating means is positioned in another one of said predetermined positions to cause a vernier adjustment of said power output regulating means in response to variation of the power output of the aircraft power plant from a predetermined value as measured by intake manifold pressure.

12. The structure as claimed in claim 9, in which the means for applying a vernier correction to said power output regulating means through said servomotor means includes a first control means operative when said power output control means is in said certain predetermined position to cause a vernier adjustment of said power output regulating means in response to variation of the rate of change of altitude from a predetermined value and a second control means operative when said power output regulating means is positioned in another of said predetermined positions to cause a vernier adjustment of said power output regulating means in response to variation of the airspeed of the aircraft from a predetermined value.

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