

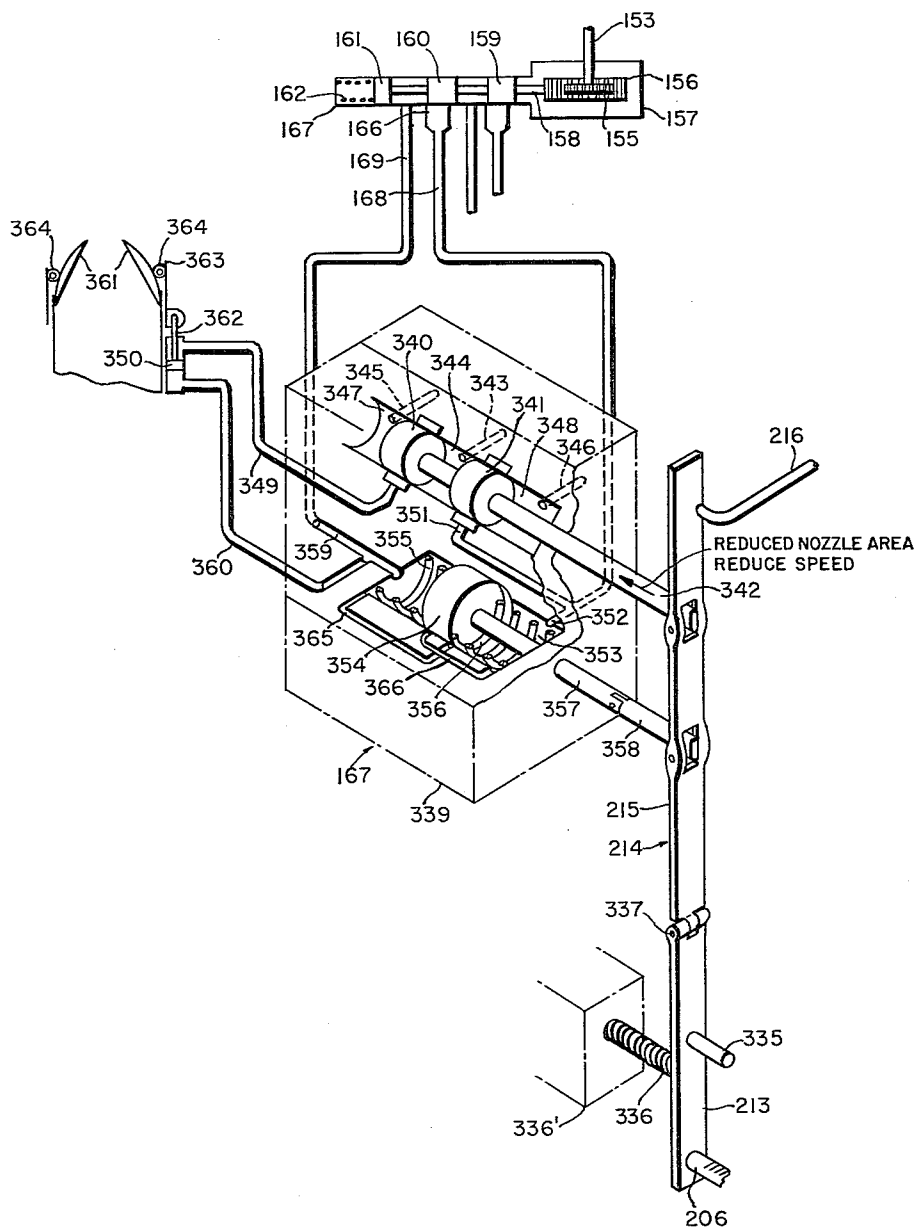
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R. T. DUNGAN ET AL

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PROPORTIONAL-PLUS-INTEGRAL COMPUTER

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INVENTORS.
RICHARD T. DUNGAN, HENRY A. LONG,
ALBERT F. STUPKA, BURT L. TAYLOR,
JAMES C. WISE

BY

R. E. Deane

ATTORNEY

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PROPORTIONAL-PLUS-INTEGRAL COMPUTER

Richard T. Dungan, Encino, Henry A. Long, San Diego, Albert F. Stupka, Van Nuys, and Burt L. Taylor, Fullerton, Calif., and James C. Wise, Cleveland, Ohio, assignors to The Marquardt Corporation, Van Nuys, Calif., a corporation of California

Original application Sept. 21, 1954, Ser. No. 457,388, now Patent No. 2,966,140, dated Dec. 27, 1960. Divided and this application Aug. 13, 1959, Ser. No. 833,478
4 Claims. (Cl. 121-41)

This invention relates to a proportional-plus-integral computer which provides a rapid dynamic response and a zero steady state error and which can be utilized as a component in turbojet control systems.

The present application is a division of application Serial No. 457,388 filed September 21, 1954, now Patent No. 2,966,140.

The computer of the present invention can be compensated by varying the time constant of the integrating portion of the computer in accordance with any desired variable, such as altitude. In a control system, the computer can be utilized to control the exhaust nozzle of the turbojet engine by selecting the exhaust nozzle area which will maintain the maximum efficiency for all flight conditions and altitudes within the operating range of the engine. By the use of suitable input linkage, the main control signal can be overridden by a secondary signal to prevent the engine from operating in an undesired manner.

It is therefore an object of the present invention to provide a proportional-plus-integral computer responsive to an input signal to provide a rapid dynamic response and a zero steady state error.

Another object of the invention is to provide a proportional-plus-integral computer in which the time constant of the integrating portion of the computer can be varied in accordance with any selected condition.

These and other objects of the invention not specifically set forth will become readily apparent from the following description and drawing.

The computer of the present invention is designated as 167. The computer body 339 has an opening for receiving valve portions 340 and 341 carried by a valve stem 342 which has one end pivotally connected to arm 215 for movement therewith. A high pressure fluid line 343 connects with space 344 between the valve portions and drain line 345 and 346 connect with spaces 347 and 348, respectively. The valve portion 340 controls the fluid flow through passage 349 which leads to one side of nozzle actuator piston 350. The valve portion 341 controls the fluid flow through passage 351 which connects with line 168 and with line 352 leading to one end of opening 353 in body 339. A piston 354 is centered within opening 353 by springs 355 and 356 and is connected to arm 215 by piston rod 357 and an arm 358, which is pivotally connected at one end to rod 357 and at the other end to arm 215. The control lever 214 has a fixed pivot point 335 against which the arm 213 of the lever is continually loaded by spring 336 carried by a fixed body 336'. Since the spring 336 bears against arm 213 at a point between the pivot point 335 and the end of input shaft 206, any movement of shaft 206 will cause arm 213 to tilt and thereby move the position of pivot pin 337 to cause a tilting of arm 215 which will result in actuation of the com-

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puter 167. The shaft 206 can be positioned by any desirable input signal, such as corrected engine speed. The movement of bar 216 is under the control of a second input signal, such as actual engine speed, so that bar 216 can override the control by the shaft 206 and cause the arm 215 to actuate the computer 167.

A passage 359 leads from the end of opening 353 which contains spring 355 and connects with line 169 and with line 360 which connects with the side of nozzle actuator piston 350 opposite the side connecting with passage 349. The exhaust end of the engine supports a variable area exhaust nozzle which can be comprised of a number of segments 361 positioned around and pivotally connected to the exhaust end of the engine. The segments are interconnected in any well-known manner to permit movement of the segments about their pivot points and still prevent leakage of exhaust between the segments. A rod 362 is connected between the actuator piston 350 and an annular ring 363 in order to move the ring along the axis of the engine. The ring 363 carries a series of rollers 364 against which the surface of the segments 361 are pressed by the pressure of the gases leaving the engine. Therefore, when the rollers 364 are moved downward, the segments will be moved inwardly to reduce the area of the exhaust nozzle and when the rollers move upward, the segments will be forced outwardly to increase the exhaust area. The difference between the position of the actuator piston 350 and the position of the actuator piston called for by the input signal from shaft 206 represents the error in the position of the actuator and of the exhaust nozzle controlled thereby.

The arm 215 is held at its pivot point with arm 358 by the spring forces on the piston 354. In the event that a force is produced on the arm 215 by either rod 206 or bar 216, the valve portions will be displaced and the piston 354 will move almost immediately to return the valve portions toward their null position, even though some error persists in the position of the exhaust nozzle. This rapid movement of piston 354 is the result of a high volume fluid flow from the valve portion to the feed back piston 354 since the valve portion opens a large pressure area for a small actual displacement. For instance, if the valve portion 341 moves to the right in the FIGURE to connect passages 351 and 352 with the high pressure line 343, the piston 354 will be moved in the opposite direction to move the valve portions back to approximately their null position. The movement of piston 354 will cause fluid to flow in line 359 and 360 to one side of the actuator piston 350 while the other side of the piston 350 will exhaust through line 349 and space 347 to drain 345. Thus, the initial movement of the actuator piston 350 will be proportioned to the error introduced to the valve portions.

The amount of movement of valve portions will determine the pressure differential across piston 354 which in turn is determined by the amount of compression of spring 355. This pressure differential will be applied across orifice 166 with the high pressure in line 168 and the low pressure in line 169. Line 168 communicates with the high pressure in lines 351 and 352 and line 169 communicates with the low pressure in lines 359 and 360 so that fluid flows from line 168 to line 169 through orifice 166. The area of orifice 166 is controlled by a valve portion 160 connected to a valve stem 158. The valve stem connects with the rack 156 which is in mesh with a pinion

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gear 155 carried by a shaft 153. Also, an end portion 161 is secured to the shaft 158 and is continually acted on by a spring 162 contained in the end of casing 167. Thus, the orifice 166 is throttled by the valve portion 160 to provide a variable integral time constant in accordance with any desired function or variable which controls the position of shaft 153. A rate of flow will exist from passage 351 through orifice 166 proportional to the pressure differential as determined by the remaining computer valve displacement which is in accordance with remaining error. The flow through orifice 166 connects with line 360 through line 169 so that the actuator piston 350 will receive fluid at a rate proportional to the error and the piston will be positioned in accordance with the time integral of the error. The time constant is determined by the position of the valve 160 which is in series with the valve portion 341 of the computer 167. Movement of the piston 350 upwardly in the FIGURE increases the exhaust area of the exit nozzle of the engine in order to increase the corrected speed and eliminate the error as introduced to arm 215 and when the error is eliminated, the shaft 206 and the arm 215 will move to null the valve portions and eliminate the differential pressure on piston 354 so that the piston can be centered by springs 355 and 356.

The same action takes place when valve portion 340 is moved to the left in the FIGURE to connect high pressure line 343 to line 349 so that the actuator piston 350 is moved in the opposite direction and the piston will exhaust through line 360 and 359 to build up the pressure on the side of the piston 354 receiving the force of spring 355. The remaining error will establish a pressure differential across orifice 166 with the high pressure in line 169 and the low pressure in line 168. The same pressure differential will be established across feed back piston 354 from the high pressure in line 360 and the low pressure in line 352. The flow through the orifice 166 from line 169 to line 168 permits the actuator piston 350 to exhaust through line 169 at a rate proportional to the existing error represented by the remaining displacement of the valve portions so that fluid will flow to the piston 350 from line 349 at a rate proportional to the error and the piston will be positioned in accordance with the time integral of the error. This movement of the piston 350 will decrease the exhaust area of the exit nozzle in order to reduce the corrected speed and eliminate the error as introduced to arm 215. The body 339 contains two unloading passages 365 and 366 which permit fluid to flow from one side of the piston to the other upon a large displacement of the piston in either direction. During engine deceleration accompanied by very large engine speed errors, the exhaust nozzle must move from closed position to approximately wide open position. During such operation, the volume of fluid displaced by the exhaust nozzle actuator piston 350 is much greater than the volume of fluid displaced by the feed back piston 354. The unloading passages serve to limit the pressure drop across the restrictor valve 166 and high pressure fluid will flow from the valve portion 341 through the unloading passage 365 directly to the actuator piston 350. In the case of engine acceleration accompanied by very large engine speed errors, the discharge in line 360 from the actuator passes around piston 354 through passage 366 and past valve portion 341. Thus, for large speed errors, the control will revert to high integration and a rapid movement of the exhaust nozzle actuator piston. The shaft 153 continually acts to adjust the integral time constant of the computer by positioning the restrictor valve 160 in accordance with a desired variable, such as a pressure which is a measure of mass flow through the engine. In such case, the position of valve 160 will vary with the acceleration rates of the engine to vary the time constant of the integrating part of the computer so that the exhaust nozzle area will vary at a rate corresponding to the acceleration rates of the engine. Various modifications of the present invention are contemplated by those skilled in

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the art without departing from the spirit and scope of the invention as hereinafter defined by the appended claims.

What is claimed is:

1. A servo unit comprising an output member, valve means having two valve members movable from a null position for controlling the application of fluid pressure to said output member to position said output member, a piston located in a fluid chamber and having a shaft connected with said valve means, opposed springs in spaces in said chamber on opposite sides of said piston for normally centering said piston, first passage means controlled by one of said valve members and connecting directly with one of said spaces on one side of said piston and with one side of said output member through an orifice, a second passage means controlled by the other valve member and connecting directly with the other side of said output member, a branch passage connecting the other of said spaces on the other side of said piston to said first passage means at a location between said orifice and said output member, said piston being displaced upon initial movement of said valve means from its null position to cause fluid pressure to be directed to said output member independently of said orifice, the displacement of said piston causing return movement of said valve means back towards but short of its null position, the remaining displacement from the null position of said valve means after the return movement causing fluid pressure to be directed to said output member through said orifice at a rate proportional to the time integral of remaining error.

2. A servo unit comprising an output means, valve means directly movable by an input signal for controlling fluid flow to position said output means, movable means rigidly connected with said valve means and normally centered by opposed biasing means, first passage means for connecting said output means to said valve means and containing an orifice, and second passage means containing said movable means and connecting said valve means to said output means to cause displacement of said movable means and said output means by fluid flow independent of said orifice upon initial movement of said valve means, the displacement of said movable means causing return movement of said valve means toward null position, said output means being displaced by fluid flow through said first passage means after return movement of said valve means by said movable means so that the initial movement of said output means is proportional to error and the additional movement is proportional to the time integral of remaining error.

3. A servo unit comprising an output member, valve means directly controlled by an input signal to control fluid flow for positioning said output member, a movable member positioned within a chamber and rigidly connected with said valve means, opposed springs within said chamber to normally center said movable member, a pair of main passages for connecting said valve means with opposite sides of said output member, orifice means within one of said main passages, and a pair of branch passages connecting opposite sides of said movable member with said one main passage at locations on opposite sides of said orifice, the initial movement of said valve means causing movement of said movable means in a direction to return said valve means towards null position, said output member being first moved by fluid flow independent of said orifice and thereafter moved by fluid flow through said orifice.

4. A servo unit comprising an output means, valve means directly movable by an input signal for controlling fluid flow to position said output means, movable means rigidly connected with said valve means and normally centered by opposed biasing means, passage means containing said movable means and connecting said valve means to said output means to cause displacement of said movable means and said output means by fluid flow upon initial movement of said valve means, and conduit means

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containing and orifice and connected to said passage means at opposite sides of said movable means, the displacement of said movable means causing return movement of said valve means towards null position, said output means being displaced by fluid flow through said conduit means after return movement of said valve means by said movable means so that the initial movement of said output means is proportional to error and the additional movement is proportional to the time integral of remaining error.

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