A two position fluid pressure responsive piston has a first effective area exposed to a reference fluid pressure, a larger second effective area exposed to a control fluid pressure, and an intermediate effective area exposed to a pressurized supply fluid from which the control fluid pressure is derived. The control fluid pressure is generated in a fluid passage connecting the pressurized supply fluid with the relatively lower reference fluid pressure and provided with first, second and third series flow restrictions and a variable area valve downstream therefrom and in series flow relationship therewith. A first passage is arranged in parallel with the second and third restrictions and a second passage is arranged in parallel with the third restriction. The control fluid pressure varies in response to opening of the variable area valve causing movement of the piston which, in turn, registers with the first and second passages to sequentially block the same causing a corresponding reduction in the control fluid pressure and a snap action of the piston to one of its two positions. Reverse movement of the piston with a hysteresis effect occurs in response to closing movement of the variable area valve which results in movement of the piston and subsequent opening of the second and first passages to cause snap action of the piston to the other of its two positions.
FIG. 1

FIG. 2
DOUBLE ACTING SNAP ACTION FLUIDIC SWITCH

BACKGROUND OF THE INVENTION

This invention relates to fluid pressure actuated switching devices of the two position type responsive to a control input signal and operative with a hysteresis effect.

Various switching devices of the above-mentioned type are known and used in control mechanisms to perform an on-off control signal function. In many cases the switching device and its associated control circuitry may not be entirely satisfactory in operation for use in an environment where reliability, accuracy, simplicity, volume, weight and/or cost cannot be neglected. One such environment is engine control apparatus for aircraft engines where maximum reliability and accuracy as well as minimum volume and weight are essential.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a fluid pressure responsive, multiple position, “snap acting” switching device having a characteristic hysteresis effect when moved from one position to another.

It is an important object of the present invention to provide a fluid pressure responsive, servo actuated, two position switching device having a hysteresis feature.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 represents a schematic view in section of the present invention.

FIG. 2 represents a series of curves having a $P_x$ fluid pressure vs servo valve position.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, numeral 10 designates a casing provided with a chamber 12 having a piston 14 slidably carried therein. The piston 14 has a reduced diameter stem or extension 16 which is stepped to provide an annular shoulder 18. Stem 16 is slidably carried in an opening 20 formed in a wall 22 separating chamber 12 from a chamber 24. Chamber 24 is provided with a port 26 which communicates via a passage 28 with a low pressure drain fluid $P_o$. A compression spring 30 interposed between piston 14 and casing 10 preloads piston 14 thereby urging annular shoulder 18 against wall 22 which acts as a stop for piston 14. A stop member 32 fixedly secured to casing 10 at the opposite end of chamber 12 is engaged by piston 14 to limit movement thereof away from wall 22.

An inlet port 34 is connected via a passage 36 to a source of pressurized fluid at pressure $P_e$. The source of pressurized fluid from which pressures $P_e$ and $P_o$ are derived is generally indicated by 38 and is conventional in that it may include fluid pump means, not shown, supplied fluid at relatively low inlet pressure $P_e$ and adapted to discharge fluid at a higher pressure $P_e$ which may be regulated to a constant value if desired. A passage 40 connects influx port 34 to a port 42 which, in turn, communicates via a passage 44 with an inlet port 46 in a casing 48 which may be remotely located from casing 10. The port 42 is vented via a passage 50 to a chamber 52 in casing 48 which chamber 52 is provided with a port 54 connected via a passage 56 to passages 28 at pressure $P_o$. A lever 58 pivotally mounted at one end to casing 48 is provided with a servo or flapper valve 60 adapted to coat with the discharge end of passage 50 to thereby vary the effective flow area thereof. The lever 58 is actuated by a rotatable cam 62 suitably disposed in chamber 52 and actuated by a control lever 64.

A plurality of fluid flow restrictions 66, 68 and 70 are disposed in passage 40 upstream from valve 60 and in series flow relationship therewith. A branch passage 72 connects passage 40 intermediate restrictions 66 and 68 with chamber 12. A branch passage 74 connects passage 40 intermediate restrictions 68 and 70 with chamber 12. A branch passage 76 connects passage 40 intermediate restriction 70 and valve 60 with chamber 12. The passage 40 upstream from restriction 66 is vented via a passage 78 to chamber 12 thereby communicating fluid at pressure $P_e$ to an intermediate effective area side $A_e$ of piston 14 which intermediate area side is effective to the effective area $A_e$ on the opposite side of piston 14 exposed to pressure $P_e$ minus the end area $A_e$ of stem 16 exposed to pressure $P_o$.

An outlet port 79 is connected via a passage 80 to chamber 12 which passage 80 is blocked as shown by piston 14 in the position shown in FIG. 1. However, piston 14 may move, in a manner to be described, away from wall 22 to unblock passage 80 thereby venting supply fluid at pressure $P_e$ from passage 78 to outlet port 79 which, in turn, may be connected via a passage 82 to fluid pressure responsive control means, not shown.

It will be noted that, in view of the ratio relationship of the areas $A_1$, $A_2$ and $A_3$ of piston 14, a force balance will exist on piston 14 at a pressure $P_e$ which has a predetermined percentage relationship relative to the pressures $P_e$ and $P_o$ opposing the same. Any deviation of pressure $P_e$ from a predetermined relationship will unbalance the piston 14 in one direction or the other depending upon the relative error in pressure $P_e$.

It will be assumed that the network shown in FIG. 1 is pressurized with fluid at the respective pressures $P_e$, $P_x$ and $P_o$. The control lever occupies a position whereby flapper valve 60 is substantially closed to generate a pressure $P_x$ upstream therefrom which unbalances piston 14 to the position shown. Movement of lever in a clockwise direction from the position shown results in opening movement of flapper valve 60 and a resulting drop in pressure $P_x$ in chamber 12 as indicated by curve A from point 1 to point 2 in FIG. 2. Upon reaching a predetermined position and thus area of flapper valve 60 whereby pressure $P_x$ which is a predetermined percentage of pressures $P_e$ and $P_o$ opposing the same, a force unbalance on piston 14 is generated in response to which the piston 14 moves away from wall 22 thereby choking flow from passage 72 to chamber 12 which causes a corresponding reduction in pressure $P_x$ in chamber 12 thereby tending to hasten the movement of piston 14 and subsequent blocking of passage 72. Blocking of passage 72 and the resulting sudden decrease in pressure $P_x$ in chamber 12 causes piston 14 to move with a snap action against stop 32 as indicated by curve A from point 2 to point 3. As the piston 14 moves into engagement with stop 32, it slides past passage 74 to block the same causing a further reduction in pressure $P_x$ thereby producing a positive holding action of piston 14 against stop 32. It will be noted that, with passages 72 and 74 blocked, all flow...
to chamber 12 is through series restrictions 66, 68 and 70 which establishes a corresponding pressure $P_x$ vs. flapper valve 60 position relationship as shown by curve B. Referring to passage 80, it will be noted that the rear side of piston 14 exposed to pressure $P_x$ approaches passage 80 as passage 72 is blocked such that substantially simultaneously with initiating the snap action of piston 14 the passage 80 is fully opened by piston 14 to vent pressure $P_x$ to output port 79 and thus passage 82 to trigger the control means, not shown, 10 connected thereto.

The piston 14 will remain seated against stop 32 until the control lever 64 is actuated to reset flapper valve 60 in a closing direction to effect a corresponding increase in pressure $P_x$ as shown in FIG. 2 from point 3 to point 4 of curve B. At point 4 of curve B, a pressure $P_x$ equivalent to that at point 2 on curve A is generated in response to which the piston 14 is unbalanced away from stop 32. The difference in position of flapper valve 60 at which the same pressure $P_x$ is generated as represented by the spread between points 2 and 4 in FIG. 2 is indicative of desired hysteresis derived from the added restriction to flow caused by blocking of passages 72 and 74 which hysteresis is for the purpose of preventing cycling of the piston 14 regardless of the position of flapper valve 60.

As the piston 14 moves away from stop 32 and traverses passage 74 to progressively open the same, the pressure $P_x$ increases rapidly causing the piston 14 to react with a snap action into engagement with wall 22 as indicated by curve B from point 4 to point 5. It will be noted that the snap action of piston 14 occurs as the front side of piston 14 exposed to pressure $P_x$ approaches passage 80 such that the passage 80 is blocked substantially instantaneously by piston 14 to depressurize output port 79 as well as the control means, not shown, responsive thereto. Movement of piston 14 from passage 74 into engagement with wall 22 results in opening of passage 72 which has the effect of increasing pressure $P_x$ accordingly to provide a positive holding action by pressure $P_x$ of piston 14 against wall 22.

It will be recognized that the output pressure signal $P_x$ derived from passage 80 is only one form of output signal which may be controlled by piston 14. If desired the passage 80 and output port 79 may be eliminated and suitable linkage means connected to piston 14 to provide a position output signal depending upon the type of control desired.

The restrictions 66, 68 and 70 may be selected with equal areas or with various area relationships depending upon the particular control characteristics desired. It will be recognized that the relative slope of curves A and B as well as intermediate curve C may be adjusted by suitable variation of the effective flow area of one or more of the restrictions 66, 68 and 70.

The spring 30 is provided to impose a relatively small force preload against piston 14 thereby holding the same against wall 22 in the absence of pressurization of piston 14.

I claim:

1. Fluid pressure responsive control apparatus comprising:
   a supply source of pressurized fluid;
   a drain source of pressurized fluid;
   conduit means connecting said supply source and drain source including first, second and third flow restrictions in series flow relationship and a variable area valve downstream therefrom and in series flow therewith for generating a control fluid pressure which varies in response to the position of said variable area valve;
   first flow passage means in series flow with said first restriction and parallel flow with said second and third restrictions;
   second flow passage means in series flow with said first and second restrictions and parallel flow with said third restriction;
   fluid pressure differential responsive means responsive to said control fluid pressure and said supply fluid pressure and operatively connected to said first and second flow passage means for controlling fluid flow therethrough depending upon the position of said pressure differential responsive means in response to a predetermined differential between said control and supply pressures;
   said pressure differential responsive means being actuated to a first position in response to a first position of said variable area valve whereby said first and second flow passage means are opened;
   said pressure differential responsive means being actuated to a second position in response to a second position of said variable area valve whereby said first and second flow passage means are blocked;
   and signal producing means operatively connected to said pressure differential responsive means.

2. Fluid pressure responsive control apparatus as claimed in claim 1 wherein:
   said pressure differential responsive means is a piston provided with opposite faces exposed to said control fluid pressure and supply pressure and adapted to slidably traverse said first and second flow passage means to vary the flow therethrough in sequence.

3. Fluid pressure responsive control apparatus as claimed in claim 2 and further including:
   a first casing having a portion of said conduit means including said first, second and third restrictions contained therein;
   a chamber in said casing slidably containing said piston;
   a second casing having a spaced-apart relationship relative to said first casing and a portion of said conduit means including said variable area valve contained therein; and
   fluid passage means defining a portion of said conduit means interconnecting said first and second casings.

4. Fluid pressure responsive control apparatus as claimed in claim 1 wherein:
   said first, second and third flow restrictions have fixed flow areas.

5. Fluid pressure responsive control apparatus as claimed in claim 2 and further including:
   said first and second positions of said piston being defined by fixed spaced-apart stop means adapted to be engaged by said piston.

6. Fluid pressure responsive control apparatus as claimed in claim 2 wherein:
   said piston is unbalanced from said first position by a decrease in said control fluid pressure and movable in response to the force imbalance thereon in a direction to close said first passage.
thereby causing a rapid drop in said control fluid pressure and corresponding increase in force unbalance imposed on said piston resulting in snap action movement of said piston into engagement with said stop means defining said second position; 

said second flow passage means being traversed and closed by said piston to produce a further decrease in said control fluid pressure thereby increasing the force unbalance imposed on said piston tending to hold the same in said second position.

7. Fluid pressure responsive control apparatus as claimed in claim 6 wherein:

said piston is unbalanced from said second position by an increase in said control fluid pressure and movable in response to the resulting force unbalance imposed thereon in a direction to open said second passage thereby causing a rapid increase in force balance imposed on said piston resulting in snap action movement of said piston into engagement with said stop means defining said first position;

said first flow passage means being traversed and opened by said piston to produce a further increase in said control fluid pressure thereby increasing the force unbalance imposed on said piston tending to hold the same in said second position.

8. Fluid pressure responsive control apparatus as claimed in claim 1 wherein:

said signal producing means includes third flow passage means connected to said conduit means upstream from said first, second and third flow restrictions for providing an output pressure signal; said fluid pressure differential responsive means being operatively connected to said third flow passage means for controlling flow therethrough depending upon the position of said flow passage means.