May 24, 1960 F. P. EVANS ET AL 2,937,656

FLOW RATE COMPENSATOR

Filed Aug. 26, 1958 3 Sheets-Sheet 1

FIG. 1

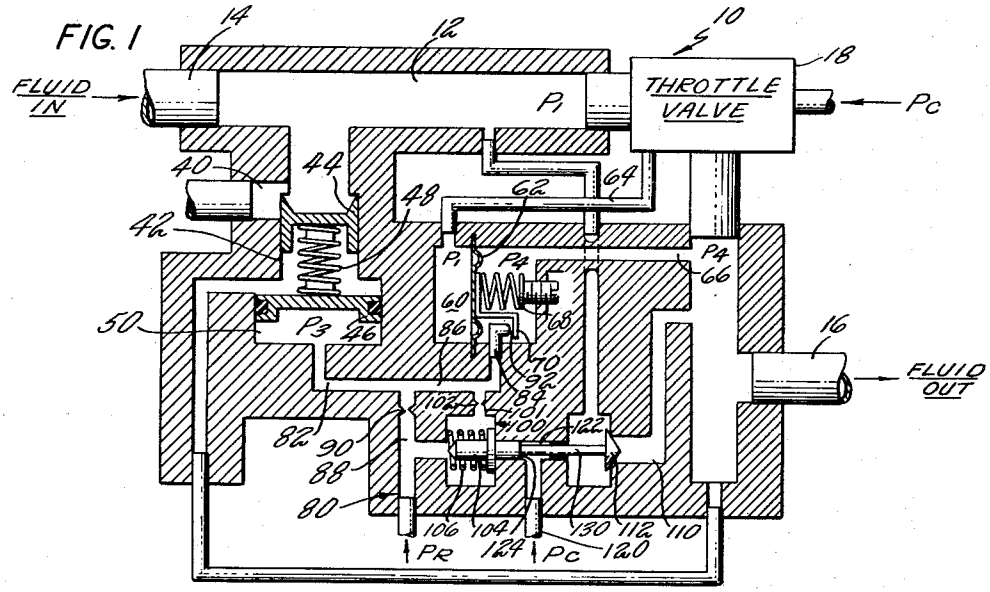


FIG. 2

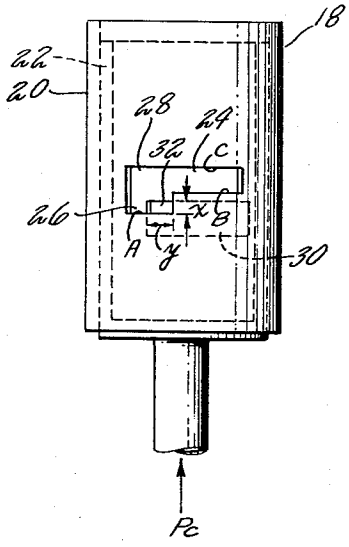


FIG. 3

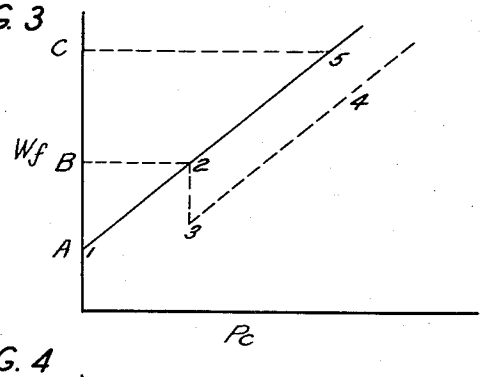
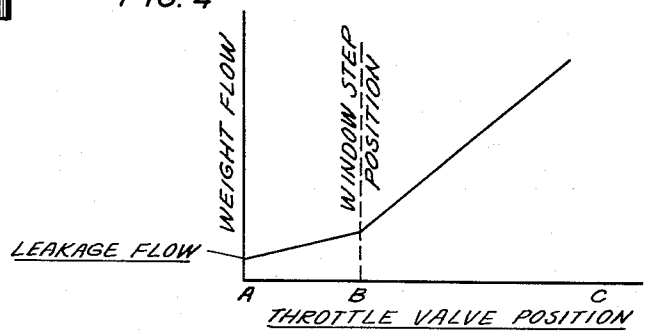


FIG. 4



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FLOW RATE COMPENSATOR

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FIG. 5

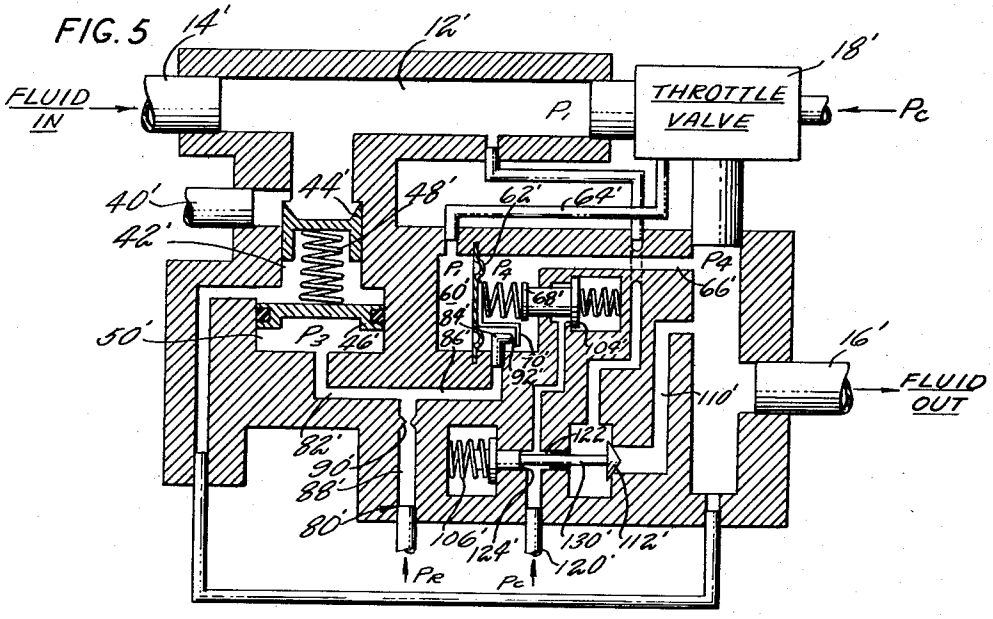
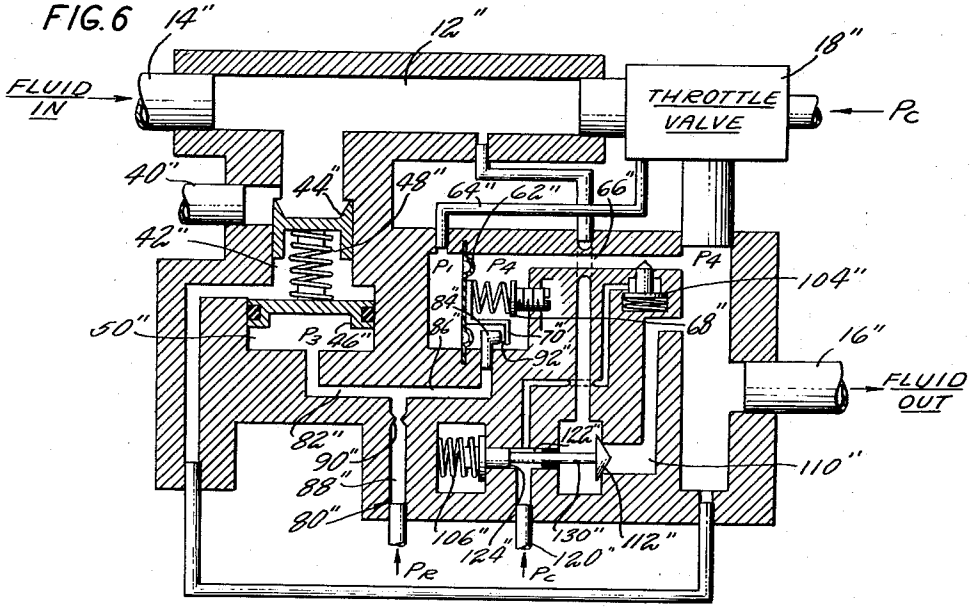


FIG. 6



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FLOW RATE COMPENSATOR

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FIG. 7

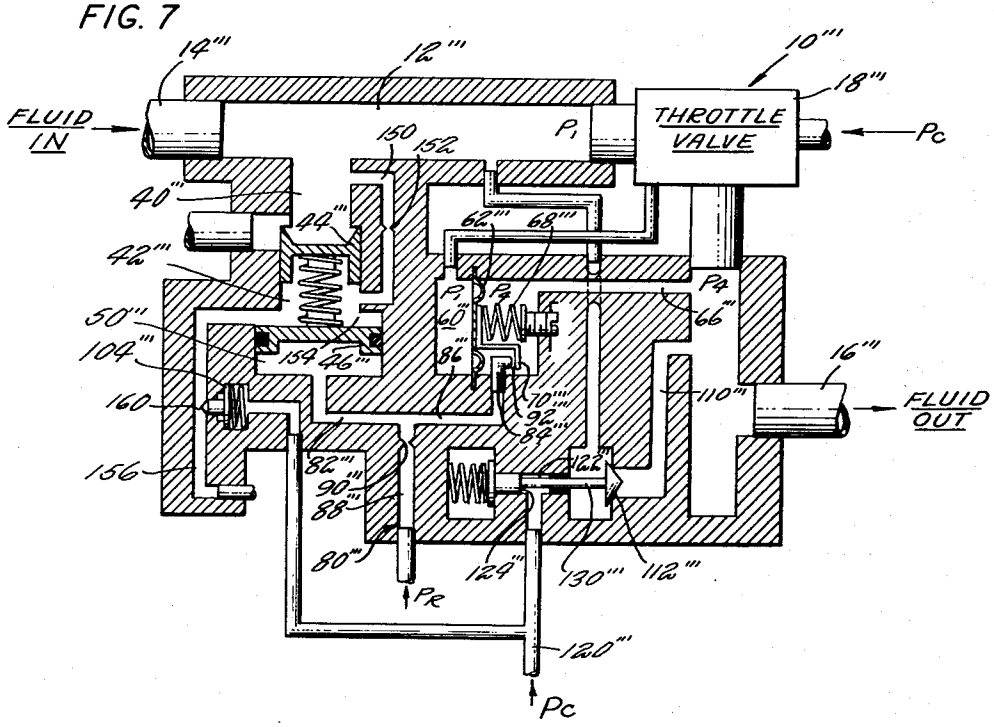
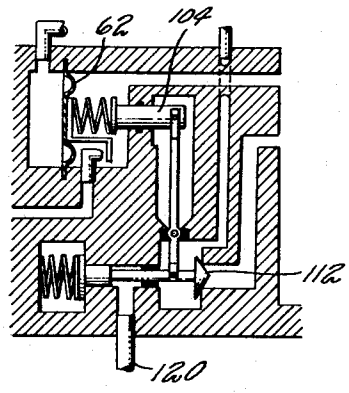


FIG. 8



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United States Patent Office 2,937,656 Patented May 24, 1960

2,937,656

FLOW RATE COMPENSATOR

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Filed Aug. 26, 1958, Ser. No. 757,305

8 Claims. (Cl. 137—110)

This invention relates to fluid control systems and more particularly to throttle valves used therein to control the rate of controlled fluid flow therethrough.

It is an object of this invention to teach a fluid control system which provides a regulated fluid flow rate regardless of the area rate of change of throttle valve metering orifice.

It is a further object of this invention to teach a fluid control system which regulates the rate of fluid flow through a throttle valve having a metering orifice defined by irregularly shaped ports so that the rate of flow is proportional to a selected control parameter which positions the throttle valve, in spite of variations in the rate of change of throttle valve orifice area for each increment of throttle valve position due to port irregularity.

It is a further object of this invention to teach control of the rate of flow through a throttle valve in a fluid control system, which throttle valve meters controlled fluid through matching ports, at least one of which is of irregular shape, by utilizing a shunt flow around the throttle valve and a reduced pressure drop thereacross when the orifice changes rapidly from a small to a large area.

It is a further object of this invention to control the pressure drop thru a throttle valve having a metering orifice defined by relatively movable, irregularly shaped ports, comprising simultaneously providing a bypass flow of fluid upstream of the diaphragm as a function of the pressure drop across the throttle valve and providing a shunt flow around the throttle valve.

Other objects and advantages will be apparent from the specification and claims, and from the accompanying drawings which illustrate an embodiment of the invention.

Fig. 1 is a schematic representation of a preferred embodiment of our fluid control system.

Fig. 2 is a schematic representation of the throttle valve used in our fluid control system and illustrating the wall ports in the fixed and movable members thereof which coact to define the throttle valve metering orifice and which are movable relative to one another to vary the area of the orifice.

Fig. 3 is a graphic representation illustrating the rate of fluid flow through our control system and shows in phantom the type of fluid flow variations which would be encountered if an irregularly ported throttle valve were used with proper regulated pressure drop across it but without the shunt flow provided by our invention.

Fig. 4 is a graphic representation of the weight flow of fluid through our fluid control system plotted against the throttle valve movable member position or control parameter valve to illustrate the fashion in which weight flow rate would vary if a throttle valve using a metering orifice defined by irregularly shaped ports were used with constant regulated pressure drop across it and without our invention.

Fig. 5 is a schematic representation of another embodiment of our invention.

Fig. 6 is a schematic representation of still another embodiment of our invention.

Fig. 7 is a schematic representation of still another embodiment of our invention.

Fig. 8 is a fragmentary schematic representation of still another embodiment of our invention.

Fig. 1 illustrates a preferred embodiment of our fluid control system 10 which is of the type taught in U.S. application Serial No. 611,339, filed September 21, 1956 by Thomas P. Farkas, and comprises a main duct system 12, through which the controlled fluid will flow, comprising upstream or fluid inlet end 14, downstream or fluid outlet end 16 and the connected ducting therebetween. Throttle valve 18 is located in the main duct system 12 between the upstream end 14 and the downstream end 16 thereof and meters the fluid passing therethru.

As best shown in Fig. 2, throttle valve 18 comprises fixed cylindrical sleeve member 20 and movable cylindrical sleeve member 22, which is coaxial with and bears against either the inner or outer surface of fixed sleeve 20. Fixed sleeve 20 has irregularly shaped wall port 24 therein which is shaped as joined small and large rectangular portions 26 and 28, respectively, while movable sleeve 22 contains rectangular wall port 30 which overlaps or aligns with stationary port 24 to define metering orifice 32 therewith. Port 30 is movable relative to port 24 so as to vary the area of metering orifice 32 as the relative positions of ports 24 and 30 change. While movable sleeve 22 of throttle valve 18 may be actuated by any desired control parameter or mechanism such as temperature and pressure ratio, for purposes of illustration it is shown to be actuatable as a function of a pressure parameter P_C. Accordingly, the fluid to be controlled which enters inlet end 14 of the main duct system 12 of our fluid control system 10 establishing a main duct system throttle valve upstream pressure P_1 upstream of throttle valve 18, is metered through orifice 32 of throttle valve 18 to establish a main duct system throttle valve pressure P_4 downstream of throttle valve 18 from whence it is discharged through outlet end 16 of main duct system 12.

Bypass line 40 communicates with main duct system 12 upstream of throttle valve 18 and contains bypass valve 42, which is positioned to regulate the amount of controlled fluid flow through bypass line 40. Bypass valve 42 comprises free floating pistons 44 and 46, which are separated by spring 48, and is subjected to pressure P_1 on one side thereof and to a reference or controlled pressure P_3, which is introduced to reference pressure chamber 50 in a manner to be described hereinafter.

Chamber 60 is divided by flexible diaphragm 62 into two chambers, the first of which is in communication with main duct system 12 upstream of throttle valve 18 through line 64 to be subjected to pressure P_1, the second of which is in communication with main duct system 12 downstream of throttle valve 18 through line 66 to be subjected to pressure P_4 so that diaphragm 62, which is biased by backup spring 68, is subjected to the pressure drop (P_1—P_4) which exists across throttle valve 18 and therefore the position of diaphragm 62 is indicative of the pressure drop across throttle valve 18. Diaphragm 62 carries flapper 70 therewith to perform a function to be described hereinafter.

First duct means 80 connects to reference pressure chamber 50 through line 82 and to fixed nozzle 84, which coacts with flapper 70 to form a variable area restriction 92, through line 86. Lines 82 and 86 join line 88 which has fixed area restriction 90 therein. A reference pressure source P_R is introduced into first duct unit 80 to pass through fixed area restriction 90 and variable area restriction 92, formed by flapper 70 and nozzle 84, to establish

reference pressure P_3 therebetween and deliver the reference pressure P_3 into reference pressure chamber **50** to act against bypass valve **42** and coact with pressure P_1 in positioning bypass valve **42** to regulate the amount of controlled fluid flow through bypass line **40**.

Second duct means **100** also communicates with line **86** and hence nozzle **84** and with reference pressure chamber **50** and is also is communication with reference pressure source P_R through duct **101**, which has fixed area restriction **102** therein. Reference pressure poppet valve **104**, which is biased open by spring **106**, is located in second duct means **100** so that when poppet valve **104** is open reference pressure source P_R is in communication with nozzle **84** and reference pressure chamber **50** through both first duct means **80** and second duct means **100** but when poppet valve **104** is closed, reference pressure source P_R is in communication with nozzle **84** and reference pressure chamber **50** through first duct means **80** only.

A shunt line or duct **110** connects to main duct system **12** both upstream and downstream of throttle valve **18** to define a controlled fluid shunt passage around throttle valve **18**. Shunt flow poppet valve **112** is positioned in shunt passage **110** so that when poppet valve **112** is closed no controlled fluid flows through shunt passage **110** but when poppet valve **112** is open, control fluid flows around throttle valve **18** through shunt line **110**. There may be installations where minimal shunt flow may be desired at all times and it may be desirable under these circumstances to cause valve **112** to establish minimal flow when in its Fig. 1 position. This minimal flow may be valve **112** leakage flow.

Control parameter such as control pressure P_C, which also actuates movable member **22** of throttle valve **18**, is introduced through line **120** into annular chamber **122** to act against surface **124**. Due to spring **106**, poppet valve **104** is open and poppet valve **112**, which is connected to poppet valve **104** through shaft **130**, is closed when control parameter P_C is below a critical pressure and such that the reverse poppet valve condition occurs when control parameter P_C is above this critical pressure. The importance of the P_C critical pressure is that the critical pressure is reached when movable port **30** of throttle valve **18** moves from alignment with small rectangular portion **26** of fixed port **24** only, into alignment with large rectangular portion **28** and small rectangular portion **26** of fixed port **24** so that for a given increment of control pressure P_C change or movable sleeve **22** position, the rate of area change or orifice **32** changes drastically since said area is defined by the overlapping rectangular ports, at least one of which is of irregular shape.

Bypass valve **42**, diaphragm **62**, variable area restriction **92** and first and second duct means **80** and **100** serve to control the pressure drop (P_1—P_4) across metering orifice **32** of throttle valve **18**. Since the opposite sides of diaphragm **62** are subjected respectively, to main duct system throttle valve upstream and downstream pressures, flexible diaphragm is actuated and positioned as a function of pressure drop (P_1—P_4) across throttle valve **18** and serves to so position restriction **70** to regulate the area of variable area flapper **92**. For the reasons more fully described in U.S. application Serial No. 663,491, filed June 4, 1957 by Thomas P. Farkas, reference pressure source P_R establishes reference pressure P_3 to act against one side of bypass valve **42** and reference pressure P_3 is a function of the area of flapper valve **92** and hence a function of the pressure drop (P_1—P_4) across throtle valve **18**. For purposes of explanation we may consider pressure P_4 to be constant and it will readily be seen that when the pressure drop across throttle valve **18** exceeds the regulated value, P_1 having increased to too great a pressure, diaphragm **62** will move flapper **70** to increase the area of variable area restriction **92** and hence reduce reference pressure P_3 to cause bypass valve **42** to open further and bypass a greater amount of controlled fluid through bypass line **40**, thereby diminishing pressure P_1 until it reaches the required value to re-establish the regulated pressure drop (P_1—P_4), whereupon diaphragm **62**, flapper **70** and bypass valve **42** will be re-established at an equilibrium position to maintain the desired pressure drop. Had the P_1 pressure reduced in value to diminish the pressure drop (P_1—P_4) below the regulated value, flexible diaphragm **62** would actuate flapper **70** to reduce the area of variable area restriction **92** and increase reference pressure P_3 to move bypass valve **42** toward a closed position, thereby reducing the flow of controlled fluid through bypass line **40** to increase pressure P_1 to the necessary value to re-establish the regulated throttle valve pressure drop (P_1—P_4).

Fluid flow control system **10** would be able to control the pressure drop across throttle valve **18** in the fashion just described without further implementation if it were not for the fact that at least one of the wall ports, **24** and **30**, in throttle valve **18** is irregular in shape.

Referring to Fig. 2 let us consider that movable wall port **30** of movable sleeve **22**, which is actuated by any controlled parameter and is illustrated to be actuated by control pressure P_C, first comes into alignment with fixed wall port **24** at point A. At point B, movable port **30** comes into alignment with the large rectangular portion **28** of port **24** while continuing in alignment with the small rectangular portion **26** thereof and continues in alignment with both the large rectangular portion **28** and the small rectangular portion **26** to point C. Fig. 2 illustrates throttle valve metering orifice **32** as being defined by wall ports **30** and **24** and being a rectangular orifice with dimensions X and Y so that the area of throttle valve orifice **32** illustrated in Fig. 2 may be calculated by the product XY. It is well known in the hydraulic field that the rate of flow through a metering orifice is proportional to the area of the orifice when the pressure drop across the orifice is maintained constant and this principle is used in our fluid flow control system **10** to regulate the rate of controlled fluid flow through throttle valve metering orifice **32** as a function of the controlled parameter P_C by regulating the area of orifice **32** as a function of parameter P_C while maintaining the pressure drop across orifice **32** constant. Continuing with our description of Fig. 2, area XY of orifice **32** will increase proportionally for each particular increment of movement of movable port **30** since orifice dimension Y will remain constant and each particular increment movement of movable port **30** will be reflected directly in the dimension X of orifice **32** and hence in the area of orifice **32** and this condition will exist between points A and B. Between points A and B, movable port **30** overlaps small rectangular portion **26** of fixed port **24** and coacts therewith to define a rectangular metering orifice **32** over a range of small areas. Once movable port **30** reaches point B, the next increment thereof toward point C will greatly increase the area of metering orifice **32** since movable port **32** will come into alignment with both the small rectangular portion **26** and the large rectangular portion **28** of fixed port **24**. From points B to C, ports **30** and **24** coact to define a metering orifice over a range of large areas.

Referring to Fig. 4 it will be noted that the rate of flow or weight flow of the controlled fluid passing through throttle valve orifice **32** will increase at a uniform rate proportional to the position of the throttle valve and the value of P_C between throttle valve positions A and B and that the rate of flow or weight flow will increase at a greater rate between throttle valve positions and P_C values B and C. This is contrary to the desired objective of control system **10**, which as stated supra, is to regulate the rate of controlled fluid flow in proportion to the value of the control parameter P_C, which is used herein to determine throttle valve position. Since the pressure drop across orifice **32** affects the rate of flow there-

through, we might reduce the pressure drop across orifice **32** when we pass beyond position B toward position C so that the throttle valve orifice area and pressure drop will bear the same relation to one another and hence give a controlled fluid flow rate proportional to throttle valve position and hence proportional to control parameter P_C whether movable port **30** is between points A and B or between points B and C. We would find, however, as best shown in Fig. 3, that if we merely reduced the pressure drop across orifice **32** in passing through point B toward point C, we would be able to maintain the controlled flow rate through orifice **32** equal on opposite sides of point B but, a sudden drop in the absolute value of the controlled fluid flow rate, W_F, would be encountered at point B before our control system **10** could be established to effect the desired rate flow coordination. Accordingly, if we merely reduce the pressure drop across orifice **32** when port **30** passes through point B toward point C our controlled fluid flow rate W_F would change from point **1** at valve position A to point **2** at valve position B before throttle valve pressure drop decrease, to point **3** at valve position B after throttle valve pressure drop decrease and thence along the desired rate line to point **4** as throttle valve position C is approached.

To overcome the difficulty just described, applicants provide shunt flow around throttle valve **18** simultaneously with throttle valve pressure drop reduction at point B so that controlled fluid flow rate W_F will move from point **1** in Fig. 3 to point **2** in Fig. 3 and, due to the combined and simultaneous action of shunt flow and throttle valve orifice pressure drop reduction at point B, will continue along the same rate line to point **5** at throttle valve position C. In this fashion the objective of regulating fluid flow rate through throttle valve **18** proportional to control parameter P_C has been accomplished even though throttle valve orifice **32** is defined by irregularly shaped window type aligned and overlapping ports **24** and **30**.

Operation

To see how the aforementioned simultaneous shunt flow and throttle valve orifice pressure drop reduction is accomplished, let us again refer to Fig. 1. As previously described, reference pressure poppet valve **104** is connected to shunt flow poppet valve **112** through shaft **130** and spring **106** biases reference pressure poppet valve **104** open and shunt flow flow poppet valve **112** closed when control parameter P_C, which acts through line **120** and annulus **122** against surface **124**, is below a predetermined value and this predetermined value is specifically selected to be the value at which control parameter P_C causes throttle valve movable port **30** to move past throttle valve point B toward throttle valve point C (Figs. 2–4). When control parameter P_C exceeds this predetermined point B value, spring **106** is overcome and reference pressure poppet valve **104** closes while shunt flow poppet valve **112** opens.

Consider first the operation of our fluid flow control system **10** when poppet valves **104** and **112** are in their Fig. 1 position. The control fluid which passes through throttle valve orifice **32** establishes a pressure drop (P_1—P_4) thereacross, which pressure drop, in the fashion described previously, is regulated by the position of flexible diaphragm **62** and flapper **70** to establish a first reference pressure P_3 which positions bypass valve **42** to cause the proper amount of controlled fluid flow through bypass line **40** to regulate pressure drop (P_1—P_4). It will be noted that in the Fig. 1 position shunt flow poppet valve **112** is closed, and there is no controlled fluid flow through shunt line **110**, further, that with reference pressure poppet valve **104** open reference pressure P_R can pass to reference pressure chamber **50** and variable area restriction **92** through both first duct means **80** and second duct means **100** thereby establishing a first reference pressure P_3 to position bypass valve **42** and to regulate the pressure drop (P_1—P_4) across throttle valve orifice **32** in the fashion described supra.

When control parameter P_C reaches the selected value at which movable port **30** passes through point B toward point C (Figs. 2–4), spring **106** is overcome and reference pressure poppet valve **104** is closed and shunt poppet valve **112** is opened. With the poppet valves **104** and **112** in their shifted positions, controlled fluid flows through shunt line **110** and fluid at reference pressure P_3 from reference source pressure P_R may pass into chamber **50** and variable area restriction **92** through first duct means **80** only, since second duct means **100** is now blocked by poppet valve **104**. This causes a reduction in the reference pressure P_3 in chamber **50** to cause bypass valve **42** to open thereby bypassing a greater amount of controlled fluid to coact with the action of shunt flow to reduce pressure P_1 thereby reducing the pressure drop across throttle valve orifice **32** to a new value ($P_{1'}$—$P_{4'}$), whereupon variable area restriction **92** reduces in area to establish a new reference pressure within chamber **50**. The change of force of the spring **68** attendant to this restriction **92** area change results in a reduced pressure drop ($P_{1'}$—$P_{4'}$) across the throttle valve orifice **32**. In this fashion the rate of flow of controlled fluid through throttle valve metering orifice **32** is maintained proportional to the value of the control parameter P_C to obtain the result illustrated graphically by solid line in Fig. 3.

A second embodiment of our invention is shown in Fig. 5 in which reference pressure poppet valve **104'** is placed in contact with spring **68'** and the position of shunt flow poppet valve **112'** is unchanged from its Fig. 1 position so that when control parameter P_C reaches its critical pressure wherein it moves movable port **30** from the throttle valve A to B position range into the throttle valve B to C position range shunt poppet valve **112'** is opened to permit shunt flow through line **110'** while throttle valve **104'** is actuated to reduce the pressure on spring **68'**, thereby permitting diaphragm **62'** to actuate flapper **70'** to increase the area of variable area restriction **92'** thereby reducing the reference pressure P_3 in control pressure chamber **50'** to cause bypass valve **42'** to increase area and bypass more controlled fluid through bypass line **40'** hence reducing the pressure drop across throttle valve **18'** simultaneously with inaugurating of shunt flow therearound. The same effect can be accomplished by mechanically linking piston **104'** to the shunt flow poppet valve **112'** as shown in Fig. 8. For purposes of clarity, additional reference numerals have been added to Fig. 5 to indicate the comparable parts illustrated in Fig. 1 such that for comparable parts Fig. 1 carries the reference numeral only while Fig. 5 carries the reference numeral primed, for example in Fig. 1 the fluid flow control system is designated as **10** whereas in Fig. 5 it is designated at **10'**. Similar methods will be used in identifying comparable parts in Figs. 6 and 7 with a double prime used with the reference numerals in Fig. 6 and triple prime with the reference numerals used in Fig. 7.

Referring to Fig. 6 we see another embodiment of our invention in which the position of shunt flow poppet valve **112''** is unchanged from the Fig. 1 position but in which reference pressure poppet valve **104''** is positioned in line **66''** to regulate the size of a variable area orifice therein. In Fig. 6, when the control parameter P_C passes through the throttle valve point B critical pressure, shunt throttle valve **112''** is caused to open to inaugurate shunt flow through line **110''** while reference pressure poppet valve **104''** is caused to open also. The normal quiescent fluid flow passing through the flapper valve **70''** creates a pressure drop across the restriction introduced by **104''**. When this restriction is removed the pressure drop ceases and the result is to cause diaphragm **62''** to move flapper **70''** in a direction to increase the area of variable area flapper valve **92''** thereby reducing the reference pressure P_3 in chamber **50''** to

open bypass valve 42'' to bypass a greater amount of controlled fluid through bypass line 42'' thereby reducing the pressure drop across throttle valve 18'' simultaneously with the inauguration of shunt line flow. The same effect can be accomplished by mechanically linking piston 104'' to the shunt flow poppet valve 112'' as generally shown in Fig. 8.

Referring to Fig. 7 we see another embodiment of our invention in which the position of shunt flow poppet valve 112''' is unchanged from the Fig. 1 configuration but a shunt line 150 with fixed restriction 152 therein connects bypass line 40''' with the volume 154 defined between pistons 44''' and 46''' of bypass valve 42''' and a second line 156, with reference pressure poppet valve 104''' constituting a variable area orifice therein, connects chamber 154 to drain. With this configuration, when the control parameter P_C reaches the previously described critical point B, shunt poppet valve 112''' opens to inaugurate flow through shunt line 110''' and reference pressure poppet valve 104 is actuated to reduce the size of variable area orifice 160 in line 150, thereby increasing the pressure within chamber 154 to move bypass valve 42''' to an increased area position, thereby increasing controlled fluid bypass flow to reduce pressure drop across throttle valve 18''' simultaneously with the inauguration of shunt flow through line 110'''. The force balance on the piston 46''' is changed by the loss of pressure in chamber 154. This requires a change in area of the flapper 92''' to effect the necessary change in controlled pressure in chamber 50'''. The spring force change attendant to the flapper area change resets the regulated pressure (P_1—P_4) to the desired new level. The piston 160 may be linked mechanically to the shunt flow poppet valve 112''' to produce the same effect.

It is to be understood that our invention is not limited to the specific embodiment herein illustrated and described but may be used in other ways without departure from its spirit as defined by the following claims.

We claim:

1. In a fluid flow control system, a throttle valve having an orifice through which the fluid must pass which orifice has two distinct area ranges, means to regulate the pressure drop across said throttle valve, and means controlling said pressure drop regulating means to vary said pressure drop across said throttle valve as said orifice changes from one of said area ranges to the other of said area ranges.

2. In a fluid flow control system, a throttle valve comprising relatively movable members having overlapping ports defining an orifice through which the fluid passing through said throttle valve is metered, at least one of said ports being of irregular shape including a small area region and a large area region so that said overlapping ports define a metering orifice which may be varied thru a range of large areas and a range of small areas, means to regulate the pressure drop across said throttle valve when said orifice is in either of said area ranges, and means to control the fluid flow rate through said system to be proportional to the relative position of said throttle valve ported members.

3. In a fluid flow control system, a throttle valve actuatable to define an orifice through which the fluid must pass which orifice has a range of small areas and range of large areas, means to regulate the pressure drop across said throttle valve, duct means defining shunt flow around said throttle valve, and means to simultaneously actuate said pressure drop regulating means to decrease said pressure drop across said throttle valve and increase fluid flow through said duct means as said orifice changes from said range of small areas to said range of large areas to cause the fluid flow rate through said throttle valve to remain constant.

4. In a fluid flow control system, a throttle valve comprising a fixed cylindrical sleeve having a wall port therein defining joined small and large rectangles and a movable cylindrical sleeve concentric and in sliding contact with said fixed sleeve and having a wall port defining a rectangle, means to actuate said movable sleeve to bring said wall ports into alignment to define an orifice through which the fluid passing through said throttle valve is metered, which orifice is varied through a range of small areas when said actuating means aligns said movable sleeve port with said small rectangle portion of said fixed sleeve port and through a range of large areas when said actuating means aligns said movable sleeve port with said large rectangle portion of said fixed sleeve port, means to regulate the pressure drop across said throttle valve when said orifice is in either of said area ranges, and means to control the fluid flow rate through said system to be proportional to the position of said movable sleeve.

5. In a fluid flow control system, a throttle valve comprising a fixed cylindrical sleeve having a wall port therein defining joined small and large rectangles and a movable cylindrical sleeve concentric and in sliding contact with said fixed sleeve and having a wall port defining a rectangle, means to actuate said movable sleeve to bring said wall ports into alignment to define an orifice through which the fluid passing through said throttle valve is metered, which orifice is varied through a range of small areas when said actuating means aligns said movable sleeve port with said small rectangle portion of said fixed sleeve port and through a range of large areas when said actuating means aligns said movable sleeve port with said large rectangle portion of said fixed sleeve port, means to regulate the pressure drop across said throttle valve when said orifice is in either of said area ranges, duct means defining shunt flow around said throttle valve, and means to simultaneously actuate said pressure drop regulating means to decrease said pressure drop across said throttle valve and increase fluid flow through said duct means as said orifice changes from said range of small areas to said range of large areas to cause the fluid flow rate through said throttle valve to be proportional to the position of said movable sleeve.

6. In a fluid flow system for controlling the flow of a fluid having a main duct system through which the controlled fluid passes, a throttle valve in said main duct system comprising a fixed cylindrical sleeve having a wall port therein defining joined small and large rectangles and further comprising a movable cylindrical sleeve concentric and in sliding contact with said fixed sleeve and having a wall port therein defining a rectangle, means to actuate said movable sleeve to bring said wall ports into alignment to define an orifice through which the controlled fluid passing through said main duct system is metered, which orifice is varied through a range of small areas when said actuating means aligns said movable sleeve port with said small rectangle portion of said fixed sleeve port and through a range of large areas when said actuating means aligns said movable sleeve port with said large and small rectangle portions of said fixed sleeve port, a chamber divided by a spring loaded flexible diaphragm and communicating with said main duct system both upstream and downstream of said throttle valve to subject one side of said diaphragm to main duct system throttle valve upstream pressure and the other side of said diaphragm to main duct system throttle valve downstream pressure, a flapper carried by said diaphragm, a fixed nozzle positioned adjacent said flapper and defining a variable area restriction therewith as said flapper moves with said diaphragm, a bypass line connected to said main duct system upstream of said throttle valve and having a pressure actuated bypass valve with first and second sides therein to regulate the controlled fluid flow therethrough which bypass valve is subjected on said first side to said main duct system throttle valve upstream pressure, first duct means including a reference pressure chamber communicating with said second side of said bypass valve and connected to said nozzle and

having a fixed restriction therein, a reference pressure source introducing pressurized fluid to said first duct means to establish a reference pressure between said fixed orifice and variable area restriction which reference pressure is proportional to the area of said variable area restriction and which reference pressure is introduced to said reference pressure chamber to act upon said second side of said bypass valve, second duct means with a fixed orifice therein connected to said nozzle and said reference pressure chamber and also subjected to said reference pressure source, a reference pressure poppet valve located in said second duct means so that fluid from said reference pressure source may flow to said nozzle and said reference pressure chamber through both said first and second duct means when said reference pressure poppet valve is open, third duct means connected to said main duct system both upstream and downstream of said throttle valve and defining a shunt flow passage around said throttle valve, a shunt flow poppet valve located in said third duct means so that no controlled fluid passes through said third duct means when said shunt flow poppet valve is closed, means to bias said shunt flow poppet valve closed and said reference pressure poppet valve open so that a first reference pressure communicates with said reference pressure chamber to coact with said main duct system throttle valve upstream pressure to position said bypass valve to control the controlled fluid pressure difference upstream and downstream of said throttle valve, and means to open said shunt flow poppet valve and close said reference pressure poppet valve when said movable sleeve wall port moves from alignment with said fixed sleeve wall port small rectangle portion into alignment with said fixed sleeve wall port large and small rectangle portions to institute controlled fluid flow through said shunt flow passage and to stop fluid flow from said reference pressure source through said second duct means thereby reducing said first reference pressure to a second reference pressure and reposition said bypass valve to permit greater controlled fluid flow through said bypass line to reduce and control the controlled fluid pressure difference upstream and downstream of said throttle valve.

7. In a fluid flow system for controlling the flow of a fluid having a main duct system through which the controlled fluid passes, a throttle valve in said main duct system comprising a fixed cylindrical sleeve having a wall port therein defining joined small and large rectangles and further comprising a movable cylindrical sleeve concentric and in sliding contact with said fixed sleeve and having a wall port therein defining a rectangle, means responsive to an actuating pressure to actuate said movable sleeve as a function of said actuating pressure to bring said wall ports into alignment to define an orifice through which the controlled fluid passing through said main duct system is metered, which orifice is varied through a range of small areas when said actuating means aligns said movable sleeve port with said small rectangle portion of said fixed sleeve port and through a range of large areas when said actuating means aligns said movable sleeve port with said large and small rectangle portions of said fixed sleeve port and which orifice changes from said range of small areas to said range of large areas when said actuating pressure is at critical value, a chamber divided by a spring loaded flexible diaphragm and communicating with said main duct system both upstream and downstream of said throttle valve to subject one side of said diaphragm to main duct system throttle valve upstream pressure and the other side of said diaphragm to main duct system throttle valve downstream pressure, a flapper carried by said diaphragm, a fixed nozzle positioned adjacent said flapper and defining a variable area restriction therewith as said flapper moves with said diaphragm, a bypass line connected to said main duct system upstream of said throttle valve and having a pressure actuated bypass valve with first and second sides therein to regulate the controlled fluid flow therethrough which bypass valve is subjected on said first side to said main duct system throttle valve upstream pressure, first duct means including a reference pressure chamber communicating with said second side of said bypass valve and connected to said nozzle and having a fixed restriction therein, a reference pressure source introducing pressurized fluid to said first duct means to establish a reference pressure between said fixed orifice and variable area flapper valve which reference pressure is proportional to the area of said variable area restriction and which reference pressure is introduced to said reference pressure chamber to act upon said second side of said bypass valve, second duct means with a fixed orifice therein connected to said nozzle and said reference pressure chamber and also subjected to said reference pressure source, a reference pressure poppet valve located in said second duct means so that fluid from said reference pressure source may flow to said nozzle and said reference pressure chamber through both said first and second duct means when said reference pressure poppet valve is open, third duct means connected to said main duct system both upstream and downstream of said throttle valve and defining a shunt flow passage around said throttle valve, a shunt flow poppet valve located in said third duct means so that no controlled fluid passes through said third duct means when said shunt flow poppet valve is closed, means to bias said shunt flow poppet valve closed and said reference pressure poppet valve open when said actuating pressure is below said critical value so that a first reference pressure communicates with said reference pressure chamber to coact with said main duct system throttle valve upstream pressure to position said bypass valve to control the controlled fluid pressure difference upstream and downstream of said throttle valve so that the rate of controlled fluid flow thru said system is proportional to said movable sleeve, and means responsive to said actuating pressure to simultaneously open said shunt flow poppet valve and close said reference pressure poppet valve when said actuating pressure is at said critical value to institute controlled fluid flow through said shunt flow passage and to stop fluid flow from said reference pressure source through said second duct means thereby reducing said first reference pressure to a second reference pressure and reposition said bypass valve to permit greater controlled fluid flow through said bypass line to reduce and control the controlled fluid pressure difference upstream and downstream of said throttle valve so that the rate of controlled fluid flow thru said system continues to be proportional to the position of said movable sleeve.

8. In a fluid flow control system, a throttle valve comprising relatively movable members having overlapping ports defining an orifice through which the fluid passing through said throttle valve is metered, at least one of said ports being of irregular shape including a small area region and a large area region so that said overlapping ports define a metering orifice which may be varied thru a range of large areas and a range of small areas, means to establish a reference pressure proportional to the pressure drop across said orifice and to bypass fluid from said system upstream of said throttle valve, means to regulate the pressure drop across said throttle valve when said orifice is in either of said area ranges, and means to establish a new reference pressure when said orifice area changes from one of said ranges to the other to control the fluid flow rate through said system to be proportional to the relative position of said throttle valve ported members.

No references cited.