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FLUID PRESSURE RESPONSIVE CONTROL MECHANISM

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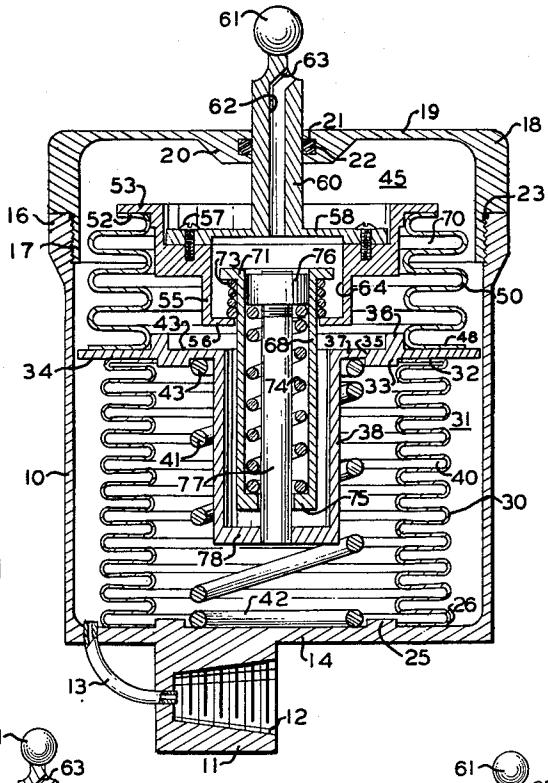



FIG. 1

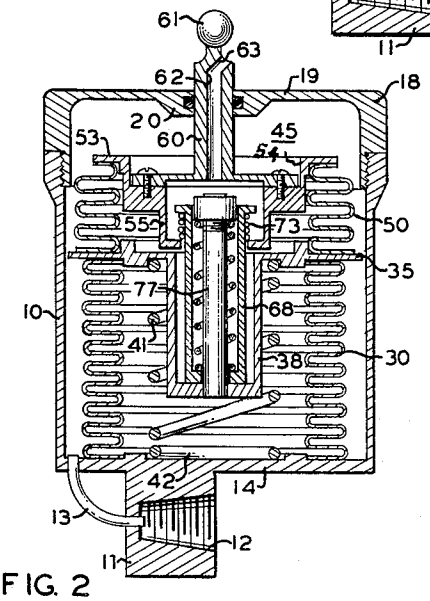



FIG. 2

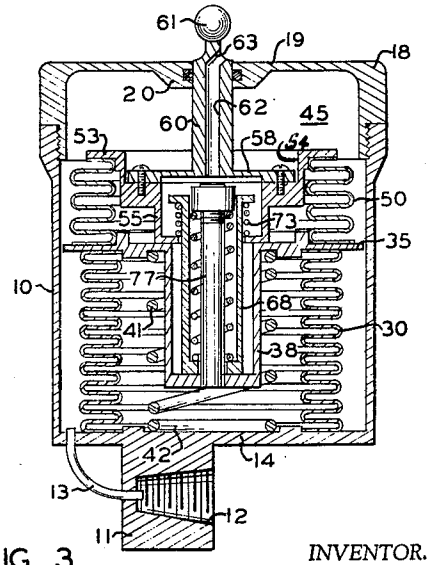



FIG. 3

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# FLUID PRESSURE RESPONSIVE CONTROL MECHANISM

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This invention relates to a fluid pressure responsive control mechanism, and is particularly concerned with means by which a control member may be actuated in response to the resultant of a plurality of variable fluid pressures. While certain aspects of the present invention may be broadly applicable to fluid pressure controls in general, the invention is more particularly concerned with the control of fuel supply instrumentalities of a fuel injection system of a multiple cylinder, four cycle, spark ignition, high speed, internal combustion engine.

In the control of such internal combustion engines, it has long been recognized that intake manifold pressure may be used as a determining factor in the control of liquid fuel supply, as distinct from a direct control of such supply. It has also been found that fuel supply control through the intake manifold pressure may be more effective, efficient, economical and responsive than management of the engine operation by direct fluid flow control, as by a fluid valve in the fuel line. Furthermore, it has been found that other important factors are involved in the accomplishment of the most effective and efficient manner of fuel supply control, as for instance, the ambient atmospheric pressure. This factor is more particularly important in aviation engines which may be subject to widely varying atmospheric pressures in response to altitude changes. It is recognized, of course, that demands for fuel vary with speed of engine revolutions, and with varying load conditions, both of which react to alter the intake manifold pressure are of course, variable despite throttle setting under the operator's control by which air intake to the manifold may be selectively adjusted.

The present invention, therefore, provides a bellows type expansible chamber device which responds to manifold pressures as well as ambient atmospheric pressures, and which further includes a zone of pressure reference with respect to the pressure applied by the intake manifold and by the atmosphere. In the present form of the invention, it is contemplated that the zone of reference may be evacuated so as to provide substantially zero pressure so that control responses will be relative to absolute pressure. However, other reference pressures may be employed preferably acting as a constant, but variables such as a temperature responsive medium may be employed to introduce further multiple responsiveness.

The present structure may be broadly defined as involving an imperforate, generally cylindrical casing in which an axially arranged first expansible chamber responsive bellows is mounted, one end being anchored to one end of the casing. One side of this first bellows is subjected to the reference pressure while the opposite side is in communication with a variable pressure such as that applied by an intake manifold. The free end of this first bellows is secured to a floating bridge which is also attached to the free end of a second, expansible chamber, pressure responsive bellows, the opposite end of which is secured to a control rod. One surface of the second bellows is also subjected to the variable pressure of intake manifold while the other side is open to atmospheric pressure. Thus the total responsive movement of the control rod is a resultant of manifold pressure and ambient atmospheric pressure acting in relation to



said reference pressure. The invention further provides limiting means by which pressure response ranges may be established beyond which activating pressures will be ineffective, permitting other activating pressures to take complete control of the resultant rod movements. While the application of this mechanism is admirably adapted for the control of fuel flow in an injection type, spark ignition, internal combustion engine, wherein pressure factors operate as hereinafter described to provide for the efficient and effective operation of the engine throughout the entire range of speeds and loads, it will be understood that the inventive concept is not limited to such application.

It is therefore among the primary objects of the present invention to provide a novel and improved pressure responsive mechanism in which the resultant motion is responsive to a sumation of individual pressure conditions.

Another object of the present invention is to provide a compound pressure responsive mechanism including a separate pressure responsive element combined in cooperation to provide for the actuation of the control mechanism in joint response to the individual pressure conditions of such independent means.

Another object of the present invention is to provide a compound, expansible chamber type, pressure responsive means including independent pressure chambers operable in combination to effect a joint movement of an operating mechanism, and to provide for means by which the effect of one or the other of such chambers may be eliminated upon the achievement of predetermined pressure conditions in the cooperating chamber.

It is also an object of the present invention to provide a device of the character set forth, including means providing a reference pressure with respect to which pressure variations applicable to a control mechanism may be related.

The invention also includes as an objective that of providing a pressure responsive element under the influence of dual pressures, one of which may be effectively zero to provide substantially absolute responses, or which may be temperature responsive to modify response in relation to ambient temperature conditions.

More specifically, it is an object of the present invention to provide a pressure responsive control mechanism for a fuel injection system of an engine by which the fuel supply may be controlled by the intake manifold pressure of the engine and in which a supervening control may be supplied by changes in the ambient atmospheric pressure. Numerous other objects, features and advantages of the present invention will be apparent from consideration of the following specifications, taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a central vertical cross section of one preferred form of the pressure responsive mechanism of the present invention;

FIG. 2 is a similar reduced cross section showing the parts in a different pressure responsive position; and,

FIG. 3 is a cross section similar to FIG. 2 showing the parts in a further pressure responsive position.

In the drawings depicting one preferred form of the present invention, here presented by way of illustration, the external casing of the mechanism is illustrated in the form of a generally cylindrical rigid body **10** formed with a depending boss **11** defining an internally threaded pressure inlet connection bore **12** from which a pressure tube **13** extends through the bottom wall **14** of the casing at a point adjacent the inner face of the wall of the body. The upper end of the body is open, being formed as at **16** with an externally protruding reinforcing rim which is internally threaded as at **17**. The internal threads **17** of the rim **16** receive and sealingly engage cap **18**, the top **19** of which extends inwardly to define a central

bearing boss 20, having an intermediate annular seat 21 for a suitable sealing member as indicated by the O-ring 22. The cap is preferably sealed with body 10 by the use of a similar O-ring 23 between the cap and the bead 16.

Within the body, sealingly anchored about the inwardly extending coaxial shoulder 25, is the lower end convolution 26 of a bellows 30 extending axially of the body and spaced inwardly from the body wall to form an annular peripheral pressure chamber 31. While the form and construction of the bellows may not be critical, that form herein preferred consists of the generally uniform cylindrical type, the walls of which define equal and successive inwardly and outwardly directed return beat undulations whereby pressure variations between that within the bellows and externally thereof will provide for a faithful response in the bellows length. The upper end convolution 32 of the bellows 30 is sealingly engaged about the depending shoulder 33 of the under face of a peripheral flange 34 of a floating bridge 35. The bridge extends inwardly from the peripheral flange 34 to provide an annular upstanding shoulder 36. A recess 37 is formed on the under face of the bridge inwardly of the depending shoulder 33 and surrounding the upper end of a cylindrical depending housing 38 extending within the bellows 30 and thus into the inner chamber 40 formed thereby. For exerting a normal upward pressure on the bridge 35 and thus a tension on the bellows 30 to normally maintain it in upwardly extending vertical expanded condition, a coil spring 41 is located within the chamber 40. The lower convolution 42 of the spring 41 is seated within the inner walls of the shoulders 25 of the bottom wall 14, while the upper end 43 of the spring surrounds the housing 38 and is received within the annular recess 37.

In considering this construction, it will be noted that the peripheral flange 34 of the bridge 35 is not in sealing engagement with the inner wall of the body 10; thus a free transfer of fluid and/or pressure is permitted from the external annular chamber 31 surrounding the bellows 30 to the chamber 45 defined within the cap 19 and above the floating bridge. As will become more apparent from a discussion of the operation of the present mechanism, it will be understood that communication through the tube 13 provides for the admission of fluid to the chamber 31 surrounding the bellows 30 and thus to the chamber 45 above the floating bridge. The chamber 40 within the bellows 30 is sealed at the bridge and to the bottom wall 14 of the body, and is adapted to provide a reference pressure relative to which the pressure admitted through tube 13 will act in expanding or contracting the bellows 30. In one preferred form of the present invention, the inner chamber 40 of the bellows 30 is evacuated to provide a relatively zero pressure against which the external pressure in chamber 31 acts, thus providing substantially absolute pressure reaction. However, expansible fluid may be provided in chamber 40; such fluid would be heat responsive and hence an ambient temperature responsive factor can be included in the control.

Mounted on the upper face of the flange 34 of the floating bridge and sealed thereto is the lower convolution 48 of a second and upper bellows 50, the general configuration of which is similar to the configuration of the lower bellows 30. It may be noted, however, that the convolutions of the upper bellows are of greater amplitude and less frequency and hence the upper bellows may more readily respond to pressure changes. The upper convolution 52 of the upper bellows is sealingly engaged with a flange 53 of a head plate formed as an annular body 54 from which depends a central cylindrical web 55 terminating in an inwardly turned and centrally apertured flange 56. Secured to the body 54 by screws 57 is a disc 58 from the center of which there extends upwardly an actuating rod 60 passing through bearing boss 20 of the cap 19 and terminating in a ball connector 61. The rod 60 is formed with a bore 62 opening to the atmosphere as at 63 and communicating through the disc 58 to an internal chamber 64 defined by the cylindrical web 55 and its flange 56. The central aperture of the flange 56 defines an opening for loosely receiving therethrough a cylindrical spring confining capsule 68. Since the capsule 68 is of less diameter than the aperture of the flange 56, the atmospheric pressure admitted through the bore 62 may freely pass from the chamber 64 to the internal chamber 70 of the upper bellows 50. The capsule 68 is open at the top and formed with an outwardly extending top flange 71 the bottom surface of which receives the upward thrust of a coil spring 73 which surrounds the upper end of the capsule 68. The lower end of spring 73 bears against the upper face of the flange 56 adjacent the central aperture thereof, thus the spring 73 normally urges the capsule in upward position through the flange 56. Within the capsule 68 there is mounted a coil spring 74, the lower end of which is seated against the terminal inturned end 75 of the capsule and extends upwardly therefrom to bear against a threadably adjustable head 76 secured upon the upper end of a stem 77 which passes through a central bore of the lower end 75 of the capsule and is secured to the upper face of the lower closed end 78 of the housing 38.

By this arrangement, it will be seen that the capsule 68 is floatingly arranged to be urged upwardly by the spring 73, such urging being opposed by the downward urge of spring 74 against the capsule end 75. The floating bridge 35 is urged upwardly by the spring 41 and the spring 74 acting upon the head 76. The actuating rod 60 being secured to the body 54 is supported by the upper convolution of the upper bellows 50. The mounting of the upper bellows on the flange 34 of the floating bridge provides for a bodily upward urging of the bellows 50 and hence the rod 60 with the upper urging of the floating bridge attached to the lower bellows 30.

Since the bore 62 provides for the admission of atmospheric pressure through the chamber 64 and through the central aperture of the flange 56, the pressure within the chamber 70 of the upper bellows 50 will be atmospheric pressure, distinct from the intake manifold pressure which is maintained on the outer face of the lower bellows 30 as well as the outer face of the upper bellows 50 through the passage of such pressure around the floating bridge and into the chamber 45.

As noted, the internal chamber 40 of the lower bellows is sealed so that whatever pressure is maintained therein is isolated and not communicated with other parts of the instrument.

In the operation of the device, it will of course be understood that pressure variations applicable to the various chambers of the apparatus may be induced by various associated instrumentalities. Thus any fluctuating pressure for purposes of primary control may be applied through the connection bore 12 and pressure tube 13 to the chambers 31 and thence past the edge of the floating bridge, to the chamber 45. Any suitable source of secondary pressure may be admitted through the duct 63 to the internal chamber 70 of the upper bellows so as to either act in unison with or in opposition to the pressure in the chambers 31 and 45 in the actuation of the rod 60 or to produce movement of the rod 60 while the pressure in chambers 31 and 45 is static. It is also to be understood that the pressure in the chamber 40 within the bellows 30 may be an effective zero pressure induced by the evacuation of the chamber so as to provide a minimum reference pressure inducing a responsive movement in the nature of absolute response or other type of pressure may be applied ot this internal chamber, such for instance as a sealed volume of temperature responsive gas which may act to induce a response in which ambient temperature conditions are a factor. As one means of discussing

the operative function of the apparatus and to illustrate a utilitarian application thereof which has been successfully employed, it may be considered that the bore **12** and the pressure tube **13** are in communication with the intake manifold of an internal combustion engine, whereby the chambers **31** and **45** are subjected to the variable pressure of such intake manifold. In this embodiment of the invention, the internal chamber **40** of the lower bellows **30** is sealed and evacuated to provide a substantially zero pressure as a pressure reference, while the duct **62** is open to communication with the atmosphere to provide for variable atmospheric pressure within the chamber **70** of the upper bellows and within the capsule **38**. In this application of the invention, the rod **60** through its ball **61** may be connected to a control mechanism for a fuel pump of such type as disclosed in my copending application, Serial No. 703,898, filed December 19, 1957, entitled "Variable Displacement Pump" to which reference may be had and which is included herein by way of reference. In this particular application of the invention, the movements of the rod are adapted to vary the volumetric output of the pump during pump rotation; and, again, in this application of the invention and pump to an internal combustion engine it will be understood that the pump is rotated by and with the internal combustion engine and at a rate commensurate with the speed of the internal combustion engine.

With the foregoing application of the invention for the control of a variable volume pump for the delivery of liquid fuel to an internal combustion engine, FIG. 1 of the present drawing illustrates the relative relation of the parts when the bore **12** is in communication with the inlet manifold and the duct **62** is open to the atmosphere and when the engine is coasting against compression with the butterfly pressure control throttle of the intake manifold closed. The rod **60** will be fully extended so as to reduce to a minimum or zero the output of the pump since under such condition there will be no requirement for fuel by the internal combustion engine. Under these conditions a high vacuum, as for instance in the nature of twenty-six inches of mercury, will be applied through the tube **13** to the chamber **31** surrounding the lower bellows **30** and to the chamber **41** surrounding the upper bellows **50**. Under such conditions, with the chamber **40** within the bellows **30** under substantially no pressure, the low manifold pressure applied in the chamber **31** will exert a minimum of force on the lower bellows **30**. The floating bridge will be urged upwardly by action of the internal spring **41**. The slightly higher pressure on the external surface of the bellows **30**, even though substantially small as compared with the evacuated internal chamber, would tend to collapse the lower bellows, however, such collapse is resisted by the spring **41** acting in an expanding direction so that the lower bellows is under these conditions in expanded position. However, since the internal chamber **70** of the upper bellows **50** is subjected to atmospheric pressure through the duct **62** while the external surface is subjected to the low pressure of the intake manifold, the upper bellows will tend to expand, lifting the head **54** with respect to the bridge **34**; such movement will tend to compress the spring **73** which resists any such upward movement of the head, but such upward movement will be imparted through the spring **73**, which is normally completely compressed by this movement to the flange **71** of the capsule **68** which movement will be resisted by spring **74**, which is partially compressed. These forces nevertheless act to urge the rod **60** outwardly and upwardly to minimize the volumetric supply of fuel by the associated pump in accordance with the lack of fuel requirements by the engine under these operating conditions.

With the internal combustion engine operating at low manifold pressure, the parts will assume the position shown generally in FIG. 2, wherein the throttle is slightly opened and the intake manifold pressure is increased over that of the position indicated in FIG. 1. For illustrative purposes it may be assumed under these conditions that the intake manifold pressure is in the neighborhood of 21 inches of vacuum. Under these circumstances the pressure on the external surface of the lower bellows **30** of FIG. 2 is higher than contemplated in the above discussion of FIG. 1 and there is therefore a greater tendency to collapse the lower bellows; however, this tendency is of course continuously resisted by the upward urging of the floating bridge by the spring **41** to the extent that the bellows **30** is slightly contracted from position of FIG. 1. At the same time, however, the increased pressure on the external surface of the upper bellows **50**, while yet under that of atmospheric pressure admitted internally of the bellows **50** through the duct **62**, will nevertheless cause a contraction of the bellows **50** as compared with the situation disclosed in FIG. 1, such contraction being materially aided by the expansion of the spring **74**, which moves the capsule **68** downwardly into engagement with the lower wall **78** of the member **38** carrying with it the control rod **60** through the spring **73** and other parts. The control rod **60** is thus lowered to increase the volumetric output of the pump to supply the engine with fuel for operation at idling speeds.

It will be noted that the spring **73** is still fully compressed as in FIG. 1, being held in that position by the tendency of the bellows **50** to expand under the influence of the atmospheric pressure inside, such tendency being great enough to overcome the spring **73** but not great enough under idling conditions to overcome the spring **74**. As manifold vacuum varies between a nominal 21 inches of mercury at idling and approximately 5 inches of mercury, said variation corresponding to selective variation of throttle position in normal engine operation, the position of the control rod **60** will vary in direct response to the movements of the lower bellows **30**, thus varying the pump output in correspondence with varying engine fuel requirements. In this connection it will be noted that the floating bridge **35**, the capsule **68**, the spring **73**, the annular body **54** and the control rod **60** all move as one unit in response to the bellows **30** over the range of manifold pressure corresponding to engine operation between idling and nearly full throttle. Over this range, the bellows **30** will cause the floating bridge to move between the position shown in FIG. 2 and the position shown in FIG. 3, said movements being responsive to the difference in the manifold pressure and the reference pressure in the zone **40**, here taken as substantially zero in order to obtain a response to absolute pressure. Under full throttle conditions, where maximum fuel is to be supplied to the engine, the intake manifold pressure will approach atmospheric pressure, as for instance to an amount of approximately 0 to 5 inches of vacuum. Under these circumstances the upper bellows will be further compressed, said compression being aided by spring **73**, so that the lower end **56** of the head **54** will be depressed to engage the upper surface of the recess **43** of the floating bridge, carrying with it the control rod **60** and thereby tending to move the pump control mechanism in such manner as to provide for the delivery from the pump of the maximum fuel supply.

From the foregoing, it will be seen that the present invention provides a pressure responsive mechanism in which the ultimate responsiveness is a reflection of two variable pressures, and in which one of such pressures is in part reacted upon by a third pressure which may be effectively zero where the internal chamber **40** of the bellows **30** is evacuated or which may be counteracted by variable temperature responsive pressure where the chamber **40** is filled by a temperature responsive medium. It will also be noted that the arrangement provides for a termination of responsive movements by mechanical contact of parts both in an intermediate stage of pressure responsiveness and further in such manner as to produce contact whereby the entire responsiveness is a reflection of one of the variable pressure mediums only. It will

of course be understood that in the construction of the present invention numerous changes, modifications and the full use of equivalents may be resorted to without departure from the spirit or scope of the invention as defined in the appended claims.

I claim:

1. A pressure responsive control device comprising a casing, a pair of sealed bellows within said casing, each defining an internal chamber and an external chamber between the sides of said bellows and the casing, a floating bridge interconnecting said bellows, and an operating rod secured to a free end of one of said bellows, the other of said bellows being substantially evacuated.

2. A pressure responsive control device comprising a casing, a pair of sealed bellows within said casing, each defining an internal chamber and an external chamber between the sides of said bellows and the casing, a floating bridge interconnecting said bellows, and an operating rod secured to a free end of one of said bellows, the other of said bellows having one end fixed to said casing and being substantially evacuated.



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