Oct. 5, 1948. L. LEE, 2D 2,450,833

CHARGE FORMING DEVICE

Filed Nov. 16, 1943 3 Sheets-Sheet 1

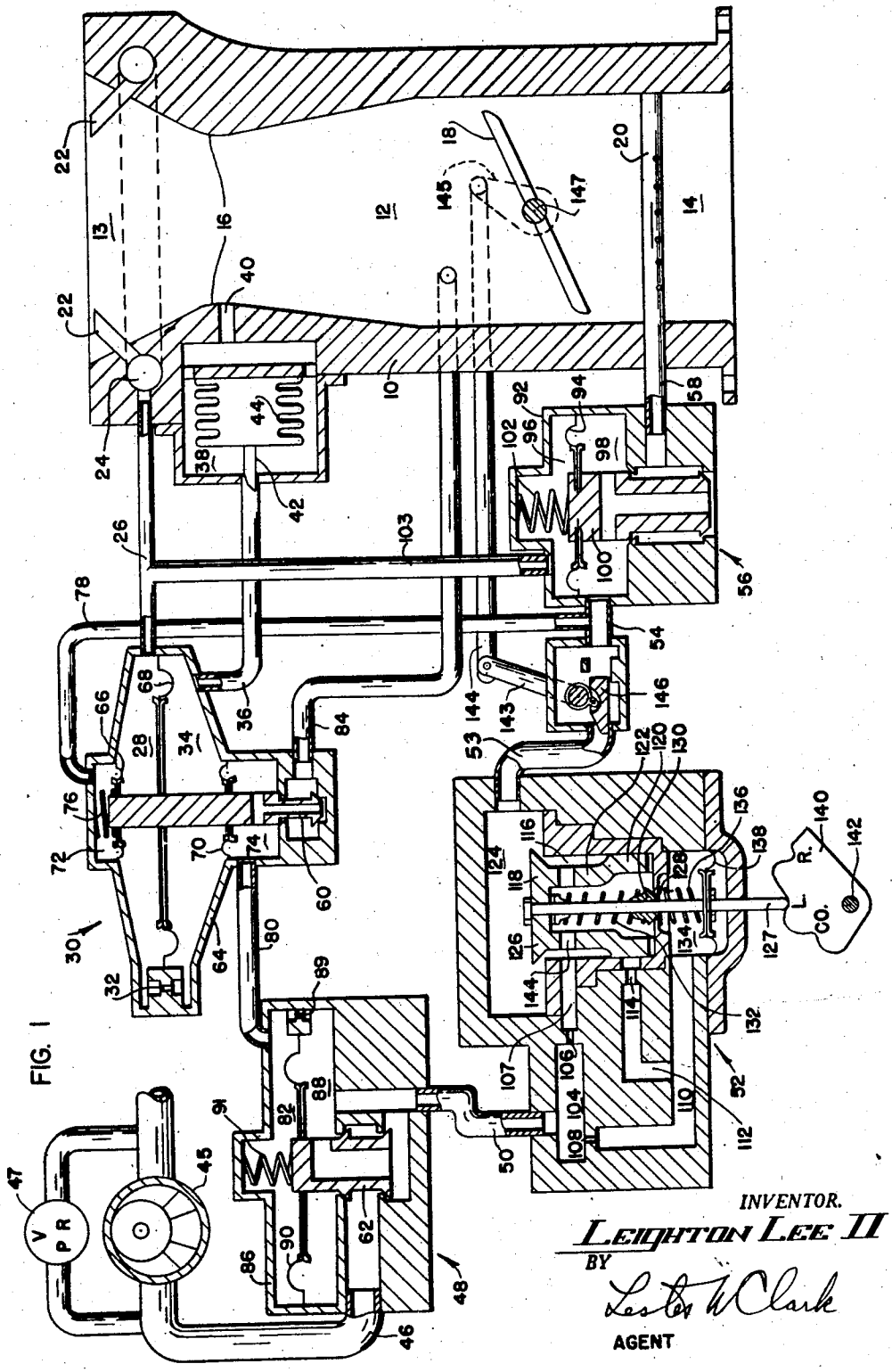


FIG. 1

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CHARGE FORMING DEVICE

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FIG. 2

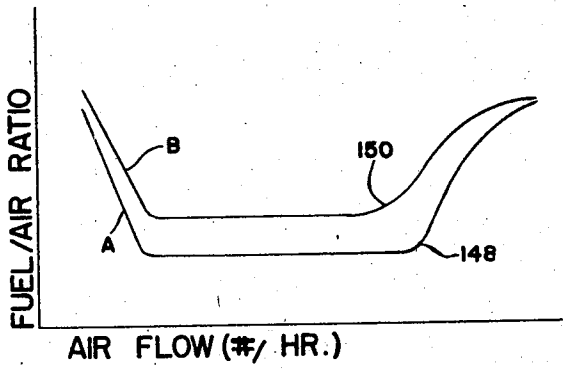


FIG. 3

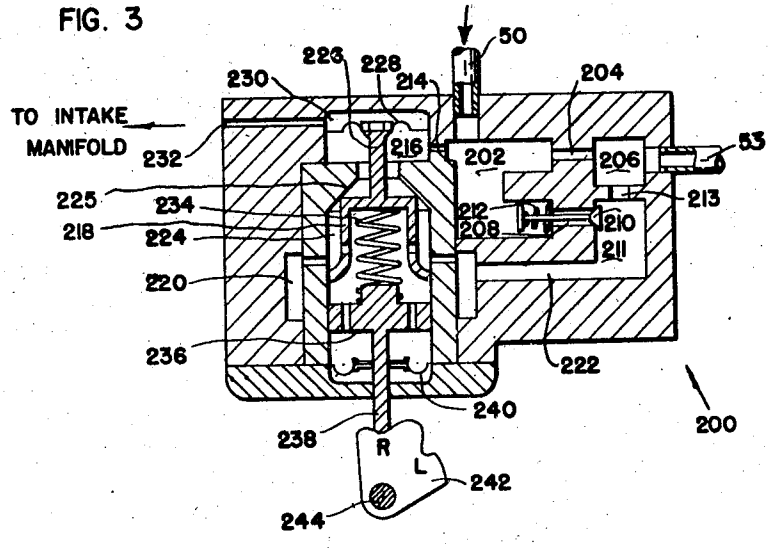
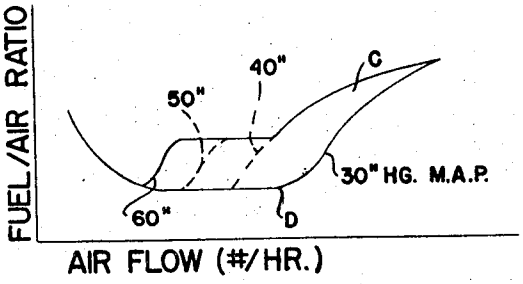


FIG. 4



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CHARGE FORMING DEVICE

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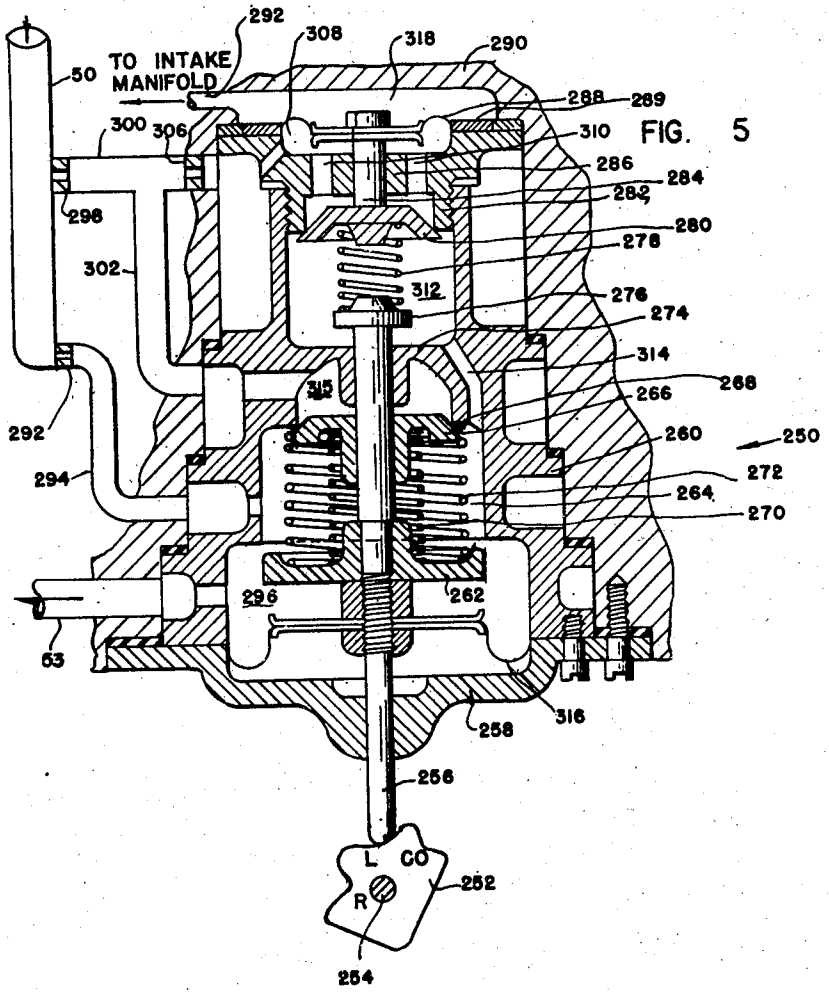


FIG. 5

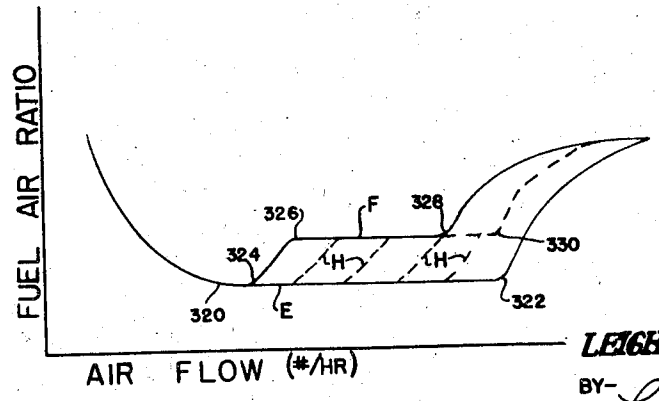


FIG. 6

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Patented Oct. 5, 1948 2,450,833

UNITED STATES PATENT OFFICE

2,450,833

CHARGE FORMING DEVICE

Leighton Lee, II, Meriden, Conn., assignor, by mesne assignments, to Niles-Bement-Pond Company, West Hartford, Conn., a corporation of New Jersey

Application November 16, 1943, Serial No. 510,454

20 Claims. (Cl. 261—41)

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The present invention relates to charge forming devices for internal combustion engines and particularly to such devices of the type wherein the quantity of fuel supplied to the engine is controlled in proportion to the quantity of air flowing to the engine.

In such carburetors, it is common to provide means for controlling the fuel flow so that the fuel-to-air ratio varies in accordance with the engine load, which may conveniently be measured by the air flow. The control of the fuel-to-air ratio as a function of air flow is usually arranged so that a high fuel to air ratio is provided at air flows less than a first predetermined value, a lower fuel to air ratio during an intermediate range of air flows, and a high fuel to air ratio when the air flow exceeds a second predetermined value. It is also common to provide a manually operable mixture control by which the pilot may select either a rich fuel-to-air ratio or a lean fuel-to-air ratio over the entire range of air flow variation.

It is an object of the present invention to provide improved means for controlling the fuel to air ratio in a fuel supply system for an internal combustion engine.

Another object of the present invention is to provide a mixture control system for a fuel supply system of the type described including a manually operable control device for selecting either a rich fuel-to-air ratio or a lean fuel-to-air ratio, and also including improved means associated with the manual control device to control the extent of the intermediate range of air flows during which the fuel to air ratio is at its lowest.

Another object of the present invention is to provide an improved mixture control system of the type described in the co-pending application of Scott F. Hunt, Serial No. 498,151, filed August 11, 1943, and assigned to the assignee of the present invention.

Another object of the present invention is to provide an improved mixture control arrangement for a fuel supply system of the type described in which the mixture is additionally controlled in accordance with the pressure in the intake manifold of the engine on which the carburetor is used.

Other objects and advantages of the present invention will become apparent from a consideration of the appended specification, claims and drawing, in which

Figure 1 is a somewhat diagrammatic illustration of a carburetor for an internal combustion engine embodying certain of the principles of my invention,

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Figure 2 is a graphical illustration of the relationship between fuel-to-air ratio and air flow in the carburetor of Figure 1,

Figure 3 is another somewhat diagrammatic illustration of a different embodiment of the principles of my invention,

Figure 4 is a graphical illustration of the relationship between the fuel-to-air ratio and air flow in the carburetor of Figure 3,

Figure 5 is a cross-sectional view of a mixture control system embodying the principles of my invention, and

Figure 6 is a graphical illustration of the relationship between the fuel-to-air ratio and air flow in a carburetor using the mixture control of Figure 5.

FIGURE 1

There is shown in Figure 1 a portion 10 of the body of a carburetor of a type used on an aircraft engine. An air passage 12 extends thru the body portion 10 from an inlet 13 to an outlet 14. Air entering the inlet 13 flows thru a Venturi restriction 16, past a throttle 18, and a fuel discharge nozzle 20 to the outlet 14.

A portion of the air entering the inlet 13 flows thru a plurality of impact tubes 22, whose ends open in a direction to receive the incoming air, to a vent ring 24 interconnecting the impact tubes 22. From the vent ring 24, this portion of the air flows thru a conduit 26, an expansible chamber 28 in a pressure meter generally indicated at 30, a restriction 32, another expansible chamber 34 in the pressure meter 30, a conduit 36, a chamber 38 and a conduit 40 to the throat of venturi 16.

A valve 42 is positioned by a flexible bellows 44 mounted in the chamber 38, and controls the flow of air from the conduit 36 into the chamber 38.

The pressure differential between the inlet 13 and the throat of venturi 16 varies with the velocity of the air flowing thru the passage 12, in accordance with the laws of fluid flow. Since air is of variable density, it is necessary to correct the pressure differential thus obtained for variations in the air density in order to secure a force which may be used as a measure of the mass of air flowing thru passage 12. This correction is made by the bellows 44, which is sealed so that the position of valve 42 varies with the pressure in the air chamber 38. The bellows 44 may be filled with nitrogen or other suitable temperature responsive fluid so that the position of valve 42 also varies in accordance with the temperature of the air in chamber 38. Since the density of the

air is determined by its temperature and pressure, it may be seen that the position of valve 42 is a function of the density of the air.

The total pressure differential between inlet 13 and the throat of venturi 16 may be considered as divided into two component pressure drops, one of which is the drop across restriction 32, and the other of which is the drop across valve 42. It may be seen that an increase in the density of the air in chamber 38 tends to open the valve 42, thereby decreasing the component pressure drop across valve 42 and increasing the component pressure drop across restriction 32. In this way, the pressure drop across restriction 32 varies not only with the velocity of the air flowing thru passage 12, but also with the density of that air. By suitably contouring the valve 42, these two effects may be proportioned so that the pressure drop across restriction 32 varies as a function of the mass of air flowing thru the passage 12 per unit of time.

The air entering inlet 13 may be compressed by a supercharger so that its pressure is considerably above atmospheric. If no supercharger is used, the air inlet is usually provided with a scoop to take advantage of the ram effect due to the motion of the aircraft thru the air.

The mixture leaving the outlet 14 of the carburetor may also be compressed by a supercharger before being delivered to the engine intake manifold.

The fuel for the internal combustion engine comes from a tank (not shown) and flows thru a pump 45 a conduit 46, a fuel pressure regulator generally indicated at 48, a conduit 50, a fuel metering or mixture control system generally indicated at 52, a conduit 53, past an idle valve 146, thru a conduit 54, a pressure regulator 56, and a conduit 58 to the fuel discharge nozzle 20. The pump 45 is provided with a pressure relief valve 47, which acts to maintain the pump discharge pressure at a substantially constant value. This relief valve may be, for example, of the type shown in the Storch et al. Patent No. 2,157,089.

The pressure meter 30 includes a pilot valve 60 which is operated in accordance with the mass of air flowing thru the carburetor and which controls a fluid pressure so as to operate a main valve 62 in the fuel regulator 48. The pressure regulator 56 maintains a substantially constant pressure on the downstream side of the mixture control 52. The mixture control 52 includes means for varying the cross-sectional area of the fuel passages extending thru it so as to vary the quantity of fuel flowing thru it for any given pressure differential across it, which pressure differential is determined by the pressure regulators 48 and 56. In other words, the mixture control 52 determines the fuel-to-air ratio for any given mass of air flowing thru the passage 12 per unit of time.

The fuel regulator 48 includes a casing 36 divided into two expansible chambers 82 and 88 by a flexible diaphragm 90. The chambers 82 and 88 are interconnected by a restriction 89. The main fuel valve 62 is attached to the center of diaphragm 90 and controls the flow of fuel from conduit 46 into chamber 88 to as to regulate the pressure in chamber 88, which is connected to conduit 50. The valve 62 is balanced against inlet pressure and is biased toward open position by a spring 91. A portion of the fuel entering chamber 88 flows thru restriction 89, chamber 82, a conduit 80, valve 60 of pressure meter 30, and conduit 84 to passage 12. The connection of conduit 84 to passage 12 is shown by way of illustration as one method of disposing of the fuel passed by pilot valve 60. That fuel might alternatively be conducted back to the fuel tank, or otherwise disposed of.

The pressure meter 30 includes a casing 64 divided by three flexible diaphragms 66, 68 and 70 into four expansible chambers 72, 28, 34 and 74. The pilot valve 60 is attached to the central portions of the diaphragms, and is biased toward closed position by a spring 76. The chamber 72 is connected by a conduit 78 to the conduit 54 downstream from the mixture control 52.

The pressure regulator 56 includes a casing 92 separated by a flexible diaphragm 94 into a pair of expansible chambers 96 and 98. A valve 100 is attached to the central portion of diaphragm 94, and is biased toward closed position by a spring 102. The chamber 98 receives fuel from conduit 54. Valve 100 controls the flow of fuel from chamber 98 into conduit 58 so as to regulate the pressure in chamber 98. The chamber 96 is vented thru a conduit 103 to the conduit 26.

The valve 100 in pressure regulator 56 is opened or closed by the diaphragm 94 as necessary to set the pressure in chamber 98 at a value which balances the pressure in chamber 96 and the force of spring 102. In this way it is insured that the pressure in chamber 98 is always higher than the pressure in chamber 96 by an amount determined by the force of spring 102. Since the pressure in chamber 96 is approximately that at the inlet 13, it is always at least equal to the pressure downstream from throttle 18. Therefore the pressure in chamber 98 is always greater than the pressure downstream from valve 100. A substantial pressure drop across valve 100 is thereby maintained to insure movement of the fuel thru it, and to prevent vaporization of the fuel at any point upstream from the valve.

The valve 100 is illustrated as being balanced against outlet pressure. If so constructed, variations in the pressure at nozzle 20, due to variations in throttle position, engine speed, etc., will not affect the position of valve 100 or the pressure in chamber 98. However, it is not necessary that valve 100 be balanced. If it were not balanced, the pressure in chamber 98 would vary with changes in throttle position, etc. However, such variations would be transmitted thru conduit 78 to chamber 72 of pressure meter 30, thereby causing pressure regulator 48 to produce a parallel and equal variation in the pressure upstream from the mixture control system 52. Therefore, variations in pressure in chamber 98 do not affect the fuel pressure differential or the rate of fuel flow thru the fuel metering system.

Fuel entering the mixture control 52 from conduit 50 first enters a chamber 104. From the chamber 104, the fuel may flow thru a fixed metering restriction 106 and a conduit 107 or thru a fixed metering restriction 108 and a conduit 110. A conduit 112 including a fixed metering restriction 114 branches off from the conduit 110. The conduits 107 and 112 terminate in a cylinder 116, in which a piston valve 118 is movable.

The piston valve 118 includes a skirt portion 120 of the same diameter as cylinder 116. When in the position shown, the skirt portion 120 closes the conduit 112. The piston valve 118 also includes a recessed portion 122 of substantially smaller diameter than cylinder 116, and located adjacent the port leading to conduit 107. The recessed portion 122 is apertured at 144 to permit the flow of fuel therethru. The upper end of

piston valve 118 extends into a chamber 124 and has a laterally extending tapered flange 126 which may be moved into engagement with the edge of cylinder 116 to prevent the flow of fuel thru the mixture control system. The chamber 124 is connected to conduit 54.

The valve 118 is operated by a stem 127 which extends longitudinally thru it and thru a port or metering restriction 128 in the bottom of cylinder 116. A metering valve 130 is slidably mounted on the stem 127, and controls the flow thru port 128. A compression spring 132 is retained between piston 118 and valve 130, and biases the valve 130 to closed position.

The conduit 110 terminates in a chamber 134 on the opposite side of port 128 from cylinder 116. A compression spring 136 is retained between the upper wall of chamber 134 and a sealing diaphragm 138 which is attached to stem 127 and extends to the casing of mixture control 52.

The lower end of stem 127 extends outside the casing of mixture control 52 and cooperates with a cam 140 fixed on a shaft 142, which may be rotated by any suitable means such as a manually operable lever (not shown).

An idle valve 146 is pivotally attached to a lever 143 connected by a link 144 to an arm 145 mounted on the shaft 147 of the throttle 18.

At very low air flows, such as are encountered under idling conditions, the pressure differential set up by the venturi 14 tends to be erratic, and is not a reliable indication of the volume of air entering the engine. The idle valve 146 controls the fuel flow directly in accordance with the throttle position at such times. The spring 76 in the pressure meter 30 acts on valve 60 in a closing direction. When the differential pressure acting on diaphragm 68 is small, as under low air flow conditions, the spring 76 becomes the predominating force acting on valve 60 in a closing direction. The closing movement of valve 60 then produced by spring 76 causes an increase in the fuel flow thru the main fuel line, since the closure of valve 60 increases the pressure in chamber 74 of pressure meter 30 and hence in chamber 82 of pressure regulator 48. Furthermore, the spring 91 of pressure regulator 48 biases valve 62 in an opening or fuel flow increasing direction.

The idle valve is normally wide open when the throttle is beyond the range of positions near its closed position, usually termed the idling range. As the throttle moves into the idling range, thereby decreasing the air flow, the idle valve 146 moves toward closed position. At the same time, the springs 91 and 76 cause operation of valve 62 in an opening direction. The valve 62 is thereby opened sufficiently so that its restrictive effect on the fuel flow is less than that of the idle valve 146. Therefore the fuel flow under idling conditions is controlled primarily by the valve 146 in accordance with the position of the throttle, and not by the pressure meter 30 in accordance with the mass of air entering the engine.

Operation of Figure 1

As previously stated, the pressure meter 30 cooperates with the pressure regulator 48 to control the pressure differential across the mixture control 52 in accordance with the quantity of air flowing thru the passage 12. In the pressure meter 30, the pilot valve 60 is positioned in accordance with the difference between a first pressure differential which is a measure of the mass of air flowing thru passage 12 and a second pressure differential which is a measure of the pressure differential

across the mixture control 52. The first pressure differential is produced across restriction 32, as previously described, and acts on the diaphragm 68 in a direction to close valve 60. The chamber 72 is connected thru conduit 78 to the downstream side of the mixture control 52. The chamber 74 is connected thru conduit 80 to chamber 82. The only force acting upwardly on diaphragm 90 is that due to the pressure in chamber 88. Two forces act downwardly on diaphragm 90, one downward force being supplied by spring 91 and the other by the pressure in chamber 82. When the diaphragm 90 and valve 62 are stationary, the upward and downward forces acting on it are balanced. Therefore, it may be seen that for all steady positions of valve 62, the pressure in chamber 82 differs from that in chamber 88 by a substantially constant amount which corresponds to the force of spring 91. The pressure in chambers 82 and 74 may therefore be used as a measure of the pressure in chamber 88 which is substantially the same as the pressure on the upstream side of the mixture control 52. The pressure in chamber 74 acts thru diaphragm 70 in a direction to open valve 60 and the pressure in chamber 72 acts thru diaphragm 66 in a direction to close valve 60. Since the pressure in chamber 74 is higher than that in chamber 72, it may be seen that the pressure differential between these two chambers is a measure of the pressure differential across the mixture control 52, and that this pressure differential acts on valve 60 in an opening direction.

When the pressure differential across the mixture control is properly proportioned with respect to the mass of air flowing thru passage 12, the various pressures acting on valve 60 are balanced and the valve is stationary. The position of valve 60 controls the pressure in chamber 74 and hence the pressure in chamber 82 and also in chamber 88 of the pressure regulator 48. Since the pressure on the downstream side of mixture control 52 is substantially constant, it may be seen that the pressure meter 30, acting thru fuel regulator 48 controls the pressure differential across the mixture control 52 in proportion to the mass of air flowing thru passage 12.

In any closed hydraulic conduit, the rate of flow of fluid thru an orifice or restriction, or thru a group of parallel restrictions such as the mixture control system 52, is determined by the cross-sectional area of the path open to the flow of fuel thru the restrictions and by the pressure differential across the restriction. In the present carburetor, the pressure differential across the mixture control system 52 is varied in accordance with the rate of flow of air thru the carburetor. Therefore, it may be stated that the total cross-sectional area open to the flow of fluid thru the mixture control 52 determines the rate of flow of fuel for a given air flow, and hence determines the fuel-to-air ratio. When the parts of mixture control 52 are in the positions shown in the drawing, fuel can flow thru the mixture control only thru the passage 107. The passage 112 is closed by the skirt portion 120 of piston valve 118, and the port 128 is closed by valve 130. The mixture control is then said to be in its lean position, as indicated by the legend "L" applied to cam 140.

Under these conditions, the relationship between the fuel and air ratio and the air flow is that indicated by the curve A in Figure 2. When the air flow is below a certain value, it is so small as compared to the cross-sectional area of venturi 16 that the pressure differential across restriction

32 is not a true measure of the mass of air flowing thru passage 12. At such times, the fuel flow is controlled primarily by the idle valve 146, as previously explained. The idle valve 146 is designed to produce a rich fuel-to-air ratio under idling conditions. This is illustrated by the upwardly extending left end portion of curve A. As the air flow increases, the force developed by the pressure differential across restriction 32 controls the fuel flow, the idle valve 146 being moved to an inactive position. The fuel and air ratio then has the low, substantially constant value illustrated in the intermediate range of air flows in Figure 2. When the air flow exceeds a value indicated by the point 148 in Figure 2, the pressure differential across the valve 130 becomes sufficient to overcome spring 132, and the valve 130 moves upwardly, opening the port 128. The fuel flow is then increased out of proportion to the increase in air flow and the fuel-to-air ratio then follows the rising curve appearing at the right end of characteristic A in Figure 2.

When the cam 140 is moved to the rich position indicated by the legend "R" in the drawing, the stem 127 is moved upwardly. The skirt portion 120 of piston valve 118 is then moved to uncover the port opening into the passage 112, and the spring 132 is partially released, thereby reducing the closing force acting on valve 130. The relationship between the fuel and air ratio and air flow then follows the curve B of Figure 2. The opening of passage 112 results in an increased fuel-to-air ratio thruout the range of air flows, while the decrease in tension of spring 132 results in the opening of valve 130 at a lower value of air flow, which may be that indicated by the point 150 in Figure 2. In this way, a better performance characteristic of the engine may be obtained when the mixture control is in the rich position and a better economy characteristic is obtained when the mixture control is in the lean position.

When the cam 140 is moved to the cut-off position indicated by the legend "CO" in the drawing, the stem 127 is moved downwardly by spring 136 until the flange 126 closes the end of cylinder 116. At such times, no fuel can flow thru the mixture control 52. This cut-off control may be used for stopping the engine.

Figure 3

Figure 3 illustrates a mixture control unit 200 which may be used in place of the mixture control unit 52 of Figure 1. Those elements in Figure 3 which correspond to equivalent elements in Figure 1 have been given the same reference characters.

Fuel entering the mixture control 200 from the conduit 50 enters a chamber 202 from which it may flow thru a fixed metering restriction 204 to a chamber 206 connected to the conduit 53. Another metering restriction 208 provides a second outlet for the fuel from chamber 202. The restriction 208 is controlled by valve 210 biased to closed position by a spring 212, and leads to a chamber 211 connected by a fixed metering restriction 213 to chamber 206.

A third outlet for fuel from chamber 202 may be traced thru a fixed metering restriction 214, an expansible chamber 216, past a metering valve 218, thru an annular passage 220 and a conduit 222 to the chamber 211.

The valve 218 is of the piston type and moves in a cylinder 224. The upper portion of cylinder 224 is tapered as at 225 so as to from a seat for the piston valve 218. A stem 226 is attached to valve 218 and extends upwardly therefrom, being attached at its upper end to a flexible diaphragm 228 which forms a wall of the chamber 216. A chamber 230 on the opposite side of diaphragm 228 is connected to the intake manifold of the engine thru a conduit 232. Altho the connection to the intake manifold, as shown, is preferred, the conduit 232 may be connected to any point in the air induction system downstream from the throttle.

A spring 234 is retained between valve 218 and a piston 236 which is also movable in cylinder 224. The spring 234 biases the valve 218 toward closed position. A stem 238 is attached to the lower side of piston 236 and extends thru a sealing diaphragm 240 to the outside of the casing of mixture control 200. The end of stem 238 cooperates with a cam 242 fixed on a shaft 244 which may be rotated by any suitable means, such as a manual lever. The valve 218 and piston 236 are apertured to facilitate ease of movement and prevent dash-pot action.

It should be noted that the pressure differential across the mixture control 200, which is a measure of the quantity of air flowing thru passage 12, and the intake manifold pressure act together in an opening direction on the valve 218. The point at which this valve opens is therefore determined by the resultant of these two conditions.

Operation of Figure 3

When the cam 242 is in the rich position, as shown in the drawing, the relationship between the fuel-to-air ratio and air flow is that illustrated by the curve C in Figure 4. The spring 234 is designed so that when piston 236 is in the position shown in the drawing, the force required to open the valve 218 is relatively low.

When the mixture control is in the lean position, so that the end of stem 238 engages the low point of cam 242 adjacent the legend L in the drawing, the spring 234 is compressed so that a greater force is necessary to open valve 218. For example, if the manifold absolute pressure is 30 inches of mercury, and the mixture control is in its lean position, the fuel and air ratio follows the curve D of Figure 4. As the manifold pressure increases to higher values, the fuel and air ratio follows the curve D only up to a certain value of air flow which varies with the manifold pressure, and then follows one of a series of generally parallel curves indicated by dotted lines in Figure 4, until finally a value of air flow is reached where the fuel and air ratio is following the characteristic curve C of Figure 4. The particular one of the dotted line curves followed by the fuel to air ratio is determined by the particular manifold pressure existing, as indicated by the legends applied to the dotted lines in Figure 4.

Figure 5

There is shown in Figure 5 a modified form of mixture control, generally indicated at 250, which may be used in place of the mixture control 52 of Figure 1 or the mixture control 200 of Figure 3. The mixture control 250 combines certain of the features of each of the other two mixture controls 52 and 200. Fuel enters the mixture control 250 through a conduit 50 and leaves through a conduit 53, which conduits may be the same as the correspondingly designated conduits of Figure 1.

The mixture control 250 may be selectively set to either rich, lean or cut-off positions by means

of a cam 252 fixed on a shaft 254. The shaft 254 may be manually rotated by any suitable lever arrangement. The cam 252 cooperates with a valve stem 256 which extends through a cover 258 into a mixture control casing 260. A valve 262 is fixed on the stem 256 within the casing 260, and cooperates with a cylinder 264 formed in the casing 260.

Another disc valve 266 is mounted for slidable movement along the stem 256. The valve 266 seats against a shoulder 268 formed in the casing 260. The valve 266 and seat 268 together form a variable metering restriction. A compression spring 270 is retained between the valves 262 and 266, and biases the latter toward closed position. Another spring 272 is retained between the shoulder 268 and the valve 262, and biases the latter toward open position.

The stem 256 extends upwardly through the valve 266 and a transverse wall 274 in the casing 260. Above the wall 274, the stem 256 is provided with a shoulder 276. A spring 278 is held in compression between the shoulder 276 and a valve 280, and tends to hold the valve 280 against a seat member 282 which is threaded into the open end of the casing 260. The valve 280 and seat 282 together form another variable metering restriction. The valve 280 is attached to a stem 284 which extends upwardly through a transverse wall 286 in the seat member 282, and at its upper end is attached to the central portion of a diaphragm 288, which is clamped at its edges between the seat member 282 and a ring 289 attached to the seat member in any suitable manner. While the inlet pressure acting on valve 280 is substantially balanced by the same pressure acting upwardly on diaphragm 288 in the construction shown, the construction may be modified to unbalance the valve if required.

The assembly consisting of casing 260, seat member 282 and their related parts is inserted in a recess in a casting 290. A chamber 318 formed between the diaphragm 288 and the casting 290 is connected through a conduit 292 to the intake manifold of the engine.

Fuel entering the mixture control 250 through the conduit 50 may flow through any of three paths to the conduit 54. One of these paths may be traced from conduit 50 through a fixed metering restriction 292, a conduit 294, cylinder 264, past valve 262 into a chamber 296 formed in the casing 260 and thence to conduit 54.

A second of these paths may be traced from conduit 50 through a fixed metering restriction 298, a conduit 300, a conduit 302, a chamber 315 formed in the casing 260, past valve 268, cylinder 264, past valve 262, through chamber 296 to conduit 54.

The third of the three paths may be traced from conduit 50, through restriction 298, conduit 300, a fixed metering restriction 306, a chamber 308 formed between diaphragm 288 and the wall 286, apertures 310 in the wall 286, past valve 280, into a chamber 312 formed in the casing 260, a conduit 314, cylinder 264, past valve 262 into chamber 296 and thence to conduit 54.

A sealing diaphragm 316 is attached at its center to the stem 256 and at its edges is clamped between cover 258 and casing 260. The fuel pressure acting on the upper side of diaphragm 316 aids in holding stem 256 against the cam 252.

Operation of Figure 5

When the parts are in the positions shown in Figure 5, the mixture control 250 is in its lean setting, as indicated by the legend on the cam 252. The valve 262 is opened so that the fuel flow is not cut off or restricted thereby, and fuel is flowing through the first of the three paths previously traced. As the air flow through the carburetor increases, the differential pressure across the mixture control 250 increases. When this pressure differential becomes sufficient to overcome spring 270, the valve 266 is moved away from its seat, thereby opening the second path previously traced for the flow of fuel.

The third path for the flowing fuel, which is controlled by valve 280 is opened not only in accordance with the fuel differential pressure across the mixture control system, but also in accordance with the intake manifold pressure acting on the diaphragm 288. Therefore the valve 280 may open sooner than the valve 266, depending upon the particular value of intake manifold pressure existing.

If the intake manifold pressure remains sufficiently low that the valve 280 does not open, and the cam 252 is in the position illustrated in the drawing, then the relationship between the fuel to air ratio and the air flow is that illustrated by the solid line curve E in Figure 6. It will be noted that this curve is substantially a straight line, from the point 320 where the carburetor leaves the idle range to a value of air flow indicated by the point 322. At the latter point, the valve 266 is opened and the fuel-to-air ratio thereafter increases rapidly until it is limited by restriction 298, whereupon the curve E again approaches the horizontal.

When the mixture control is in the rich position, so that the stem 256 engages the low point marked R on the cam 252, then the relationship between fuel and air ratio and air flow follows the solid line curve indicated at F' in Figure 6. Under these conditions the stem 256 is low, so that the tension of both springs 270 and 278 is reduced, thereby permitting the valves 266 and 280 to open at lower values of fuel pressure differential. The valve 280 then opens at the point 324 in Figure 6 and is fully opened by the time the point 326 is reached. The valve 266 opens at the point 328.

Under the conditions just described, the force of spring 278 determines the air flow at which point 324 occurs. If the force of spring 278 is sufficiently reduced, this system could be arranged so that the curve F' would not extend below its horizontal portion. Such a modification of spring 278 might require corresponding modifications of cam 252 and diaphragm 288.

When the mixture control is in the lean position illustrated in the drawing, and the intake manifold pressure is high enough to cause opening of valve 280 at a lower value of pressure differential than that indicated by point 322, then the relationship between fuel-to-air ratio and air flow follows the solid line curve E until the valve 280 opens, whereupon the relationship follows one of a family of curves shown in dotted lines in Figure 6 and marked with the letter H. The particular one of the curves H selected depends upon the intake manifold pressure. It will be noted that these dotted line curves carry the fuel and air ratio up to a value corresponding to that of the flat part of the solid line curve F, which corresponds to a fully open position of valve 280. As the air flow continues to increase, the fuel and air ratio then remains at the same value until the point 330 is reached, whereupon the valve 266 is opened and the fuel-to-air ratio

again increases rapidly until it is limited by restriction 298, whereupon the curve again approaches the horizontal.

It will be noted that the points 322 and 330 correspond to the same values of air flow. The difference between the air flow at 322 and 330 and the air flow at point 328 is caused by the difference in the loading of spring 270 because of the movement of stem 256 by cam 252.

While I have shown and described certain preferred embodiments of my invention, other modifications thereof will readily occur to those skilled in the art and I therefore intend my invention to be limited only by the appended claims.

I claim as my invention:

1. A fuel supply system for an internal combustion engine including a fuel pump, a fuel conduit extending from said pump to said engine, a first metering restriction in said conduit, means for varying the pressure differential across said restriction to control the fuel flow therethru, first valve means for controlling the cross-sectional area of said restriction in accordance with said pressure differential, spring means biasing said first valve means to closed position and acting in opposition to said pressure differential, a second metering restriction connected in parallel with said first restriction, second valve means for controlling the flow thru said second restriction, second spring means biasing said second valve means to closed position, manually operable means for opening said second valve means against said second spring means, and means operative as an incident to opening of said second valve means to reduce the tension of said first spring means so that said first valve means opens at a lower pressure differential.

2. A fuel supply system for an internal combusion engine comprising a first conduit for air flowing to said engine for combustion purposes, means associated with said conduit for producing two unequal pressures whose difference is a measure of the quantity of air flowing therethru, a fuel pump, a main fuel conduit extending from said pump to said engine, means responsive to said difference of pressures for controlling the flow of fuel thru said fuel conduit, a plurality of parallel branch fuel conduits, a metering restriction in each of said branch conduits, a cylinder forming a connection between said branch conduits and said main conduit, one of said branch conduits opening into a port in one end of said cylinder, the others of said branch conduits opening into ports in the sides of said cylinder, and said main conduit opening into the other end of said cylinder, a piston valve movable in said cylinder, said valve being effective upon movement in one direction first to close one of said lateral ports and then to close said other end of said cylinder, a poppet valve for controlling the port in said one end of cylinder, compression spring means extending between said poppet valve and said piston valve and biasing said poppet valve to closed position, and means for controlling the ratio of fuel to air supplied to said engine including manually operable means for moving said piston valve so as to control said lateral ports and to change the force of said compression spring means.

3. A fuel supply system for an internal combustion engine comprising means for measuring the quantity of air flowing to said engine for combustion purposes, a fuel conduit, means responsive to said air measuring means to control the quantity of fuel supplied to said engine thru said conduit, mixture control means for controlling the ratio of fuel to air supplied to said engine, said mixture control means including a pair of parallel metering restrictions in said conduit, a valve controlling the fuel flow thru one of said restrictions and subject to a force acting in an opening direction and varying in accordance with said quantity of air, spring means biasing said valve for movement toward closed position, a second valve controlling the fuel flow thru the other of said restrictions, manually operable means for operating said second valve, and means forming a part of said second valve for varying the force of said spring means.

4. A fuel supply system for an internal combustion engine including a fuel pump, a fuel conduit extending from said pump to said engine, a pair of parallel metering restrictions in said conduit, means for varying the pressure differential across said restrictions to control the fuel flow therethru, a first and second valve means for coordinately controlling the cross-sectional area of said restrictions in accordance with said pressure differential, a first spring biasing the said first valve means toward closed position; a second spring associated with both of said valve means for biasing the said second valve means toward closed position and the said first valve means toward open position, additional means for applying an opening force to one of said valve means, and means for simultaneously varying the tension of both said spring means.

5. A fuel supply system for an internal combustion engine including a fuel pump, a fuel conduit extending from said pump to said engine, a pair of parallel metering restrictions in said conduit, means for varying the pressure differential across said restrictions to control the fuel flow therethru, a pair of valves for coordinately controlling the cross-sectional area of said restrictions in accordance with said pressure differential, a spring operatively associated with each of said valves respectively for biasing said valves toward closed position in opposition to said pressure differential, one of said springs also biasing one of said valves toward open position, means responsive to the pressure in the intake manifold of said engine for applying an additional opening force to one of said valves, and means for simultaneously varying the tension of both said springs.

6. A fuel supply system for an internal combustion engine, including a conduit for fuel flowing toward said engine, a plurality of parallel metering restrictions in said conduit, means for controlling the fuel pressure differential across said restrictions to regulate the fuel flow therethru, a first valve for controlling the flow thru one of said restrictions in accordance with said fuel pressure differential, a second valve for controlling the flow thru another of said restrictions, spring means biasing said first valve to closed position, a cut-off valve in series with all said parallel restrictions, a stem for said cut-off valve, retainer means for said spring means attached to said stem and effective to vary the valve closing force of said spring means in accordance with the position of said stem, cam means for moving said stem, a manual operator for said cam means movable between a first position wherein said cut-off valve is closed, a second position wherein said cut-off valve is open and the force of said spring means is set at a first predetermined value, and a third position wherein said cut-off valve is open and the force of said spring

means is set at a second predetermined value, and means connecting said second valve and said stem and effective to influence said second valve in an opening sense when said operator is moved to its third position.

7. A fuel supply system for an internal combustion engine, including a conduit for fuel flowing toward said engine, a plurality of parallel metering restrictions in said conduit, means for controlling the fuel pressure differential across said restrictions to regulate the fuel flow therethru, a first valve for controlling the flow thru one of said restrictions in accordance with said fuel pressure differential, spring means biasing said valve to closed position, a cut-off valve in series with all said parallel restrictions, a stem for said cut-off valve, retainer means for said spring means attached to said stem and effective to vary the valve closing force of said spring means in accordance with the position of said stem, cam means for moving said stem, and a manual operator for said cam means movable between a first position wherein said cut-off valve is closed, a second position wherein said cut-off valve is open and the force of said spring means is set at a first predetermined value, and a third position wherein said cut-off valve is open and the force of said spring means is set at a second predetermined value.

8. A fuel supply system for an internal combustion engine, including a conduit for fuel flowing toward said engine, a plurality of parallel metering restrictions in said conduit, means for controlling the fuel pressure differential across said restrictions to regulate the fuel flow therethru, a first valve for controlling the flow thru one of said restrictions in accordance with said fuel pressure differential, spring means biasing said valve to closed position, a second valve for controlling the flow thru another of said restrictions, retainer means for said spring means, means for positioning said retainer means to vary the valve closing force of said spring means, cam means for moving said positioning means, a manual operator for said cam means movable between a first position wherein the force of said spring means is set at a first predetermined value, and a second position wherein the force of said spring means is set at a second predetermined value lower than said first value, and means connecting said second valve and said positioning means and effective to influence said second valve in an opening sense when said operator is moved to its second position.

9. A fuel supply system for an internal combustion engine, including a conduit for fuel flowing toward said engine, a plurality of parallel metering restrictions in said conduit, means for controlling the fuel pressure differential across said restrictions to regulate the fuel flow therethru, a first valve for controlling the flow thru one of said restrictions in accordance with said fuel pressure differential, spring means biasing said valve to closed position, a second valve for controlling the flow thru another of said restrictions, means for varying the valve closing force of said spring means, a manual operator for said force varying means movable between a first position wherein the force of said spring means is set at a first predetermined value, and a second position wherein the force of said spring is set at a second predetermined value lower than said first value, and means connecting said second valve and said operator and effective to influence said second valve in an opening sense when said operator is moved to its second position.

10. A fuel supply system for an internal combustion engine, including a conduit for fuel flowing toward said engine, a plurality of parallel metering restrictions in said conduit, means for controlling the fuel pressure differential across said restrictions to regulate the fuel flow therethru, a first valve for controlling the flow thru one of said restrictions in accordance with said fuel pressure differential, spring means biasing said valve to closed position, a second valve for controlling the flow thru another of said restrictions, means for varying the valve closing force of said spring means, a manual operator for said force varying means movable between a first position wherein the force of said spring means is set at a first predetermined value, and a second position wherein the force of said spring is set at a second predetermined value lower than said first value, and means rigidly connecting said second valve and said operator and effective to open said second valve when said operator is moved to its second position.

11. A fuel supply system for an internal combustion engine, including a conduit for fuel flowing toward said engine, a plurality of parallel metering restrictions in said conduit, means for controlling the fuel pressure differential across said restrictions to regulate the fuel flow therethru, a first valve for controlling the flow thru one of said restrictions in accordance with said fuel pressure differential, spring means biasing said valve to closed position, a second valve for controlling the flow thru another of said restrictions, means for varying the valve closing force of said spring means, a manual operator for said force varying means movable between a first position wherein the force of said spring means is set at a first predetermined value, and a second position wherein the force of said spring is set at a second predetermined value lower than said first value, and spring means flexibly connecting said operator and said second valve and effective to influence said second valve in an opening sense when said operator is moved to its second position.

12. A fuel supply system for an internal combustion engine, including a conduit for fuel flowing toward said engine, a plurality of parallel metering restrictions in said conduit, means for controlling the fuel pressure differential across said restrictions to regulate the fuel flow therethru, a first valve for controlling the flow thru one of said restrictions, said valve being unbalanced so that said fuel pressure differential tends to open said valve, means including a spring for applying a closing force to said valve in opposition to said fuel pressure differential, a second valve for controlling the flow thru another of said restrictions, means for operating said second valve selectively to open and closed positions, and means operative as an incident to operation of said second valve to vary the closing force acting on said first valve, said last-named means being effective when said second valve is opened to decrease the closing force acting on said first valve and effective when said second valve is closed to increase the closing force acting on said first valve.

13. A fuel supply system for an internal combustion engine, including a conduit for fuel flowing toward said engine, a plurality of parallel metering restrictions in said conduit, means for controlling the fuel pressure differential across

said restrictions to regulate the fuel flow therethru, a first valve for controlling the flow thru one of said restrictions, said valve being unbalanced so that said fuel pressure differential tends to open said valve, means including a spring for applying a closing force to said valve in opposition of said fuel pressure differential, a second valve for controlling the flow thru another of said restrictions, means for operating said second valve selectively to open and closed positions, and means operative as an incident to operation of said second valve to vary the net closing force acting on said first valve, said last-named means being effective when said second valve is opened to establish a first predetermined value of said fuel pressure differential at which said first valve opens and effective when said second valve is closed to establish a second predetermined value of said fuel pressure differential at which said first valve opens, said second value being greater than said first value.

14. Fluid flow controlling apparatus, comprising a fluid conduit, a plurality of parallel branch conduits connecting spaced portions of said main conduit, at least one metering restriction in each said branch conduit, a first valve for controlling the flow thru one of said restrictions in accordance with the fluid pressure differential thereacross, a second valve for controlling the flow thru another of said restrictions, spring means biasing said first valve to closed position, a cut-off valve in series with all said parallel restrictions, a stem for said cut-off valve, retainer means for said spring means attached to said stem and effective to vary the valve closing force of said spring means in accordance with the position of said stem, cam means for moving said stem, a manual operator for moving said cam means between a first position wherein said cut-off valve is closed, a second position wherein said cut-off valve is open and the force of said spring means is set at a first predetermined value, and a third position wherein said cut-off valve is open and the force of said spring means is set at a second predetermined value, and means connecting said second valve and said stem and effective to influence said second valve in an opening sense when said operator is moved to its third position.

15. Fluid flow controlling apparatus, comprising a fluid conduit, a plurality of parallel branch conduits connecting spaced portions of said main conduit, at least one metering restriction in each said branch conduit, a first valve for controlling the flow thru one of said restrictions in accordance with the fluid pressure differential thereacross, spring means biasing said valve to closed position, a second valve for controlling the flow thru another of said restrictions; means for varying the valve closing force of said spring means, a manual operator for said force varying means movable between a first position wherein the force of said spring means is set at a first predetermined value, and a second position wherein the force of said spring means is set at a second predetermined value lower than said first value, and means connecting said valve and said operator and effective to influence said second valve in an opening sense when said operator is moved to its second position.

16. Fluid flow controlling apparatus, comprising a fluid conduit, a plurality of parallel branch conduits connecting spaced portions of said main conduit, at least one metering restriction in each said branch conduit, a first valve for controlling the flow thru one of said restrictions, said valve being unbalanced so that the fluid pressure differential across said restriction tends to open said valve, means including a spring for applying a closing force to said valve in opposition to said fluid pressure differential, a second valve for controlling the flow thru another of said restrictions, means for operating said second valve selectively to open and closed positions, and means operative as an incident to operation of said second valve to vary the net closing force acting on said first valve, said last-named means being effective when said second valve is opened to establish a first predetermined value of said fluid pressure differential at which said first valve opens and effective when said second valve is closed to establish a second predetermined value of said fluid pressure differential at which said first valve opens, said second value being greater than said first value.

17. A fuel supply system for an internal combustion engine, comprising a first main conduit for conveying combustion air to said engine, a second main conduit for conveying fuel to said engine, first and second parallel branch conduits connected in series with said second main conduit, a mixture control valve located at a junction of said parallel branch conduits and said second main conduit, said mixture control valve being movable between a first position wherein only said first parallel branch conduit is open to the flow of fuel and a second position wherein both of said parallel branch conduits are open to the flow of fuel, first and second fixed metering restrictions in said first and second parallel branch conduits, respectively, means responsive to the rate of flow of air through said first main conduit for regulating the fuel pressure differential across said restrictions to control the rate of flow of fuel therethru, said pressure differential regulating means, said restrictions and said mixture control valve co-operating when said mixture control valve is in said first position to maintain a first predetermined fuel-to-air ratio and when said mixture control valve is in said second position to maintain a second predetermined fuel-to-air ratio greater than said first ratio, a single enrichment valve connected in parallel with said restrictions, said enrichment valve being acted upon in an opening sense by said fuel pressure differential, spring means biasing said enrichment valve toward closed position, and means effective upon movement of said mixture control valve from said first to said second positions to vary in a valve-opening sense a force acting on said enrichment valve, said enrichment valve and said force varying means co-operating with said pressure differential regulating means to increase the fuel-to-air ratio above said first predetermined value at a first fuel pressure differential value when said mixture control valve is in said first position and to increase the fuel-to-air ratio above said second predetermined value at a second lower fuel pressure differential value when said mixture control valve is in said second position.

18. Fluid flow control apparatus, comprising a main conduit, a pair of parallel branch conduits connecting two spaced portions of said main conduit, a selector valve at one of the junctions of said branch conduits with said main conduit, said selector valve being movable between a first position wherein only one of said branch conduits is open and a second position wherein both of said branch conduits are open, metering restrictions in each of said branch conduits, said

selector valve being effective upon movement to said first and second positions to establish respectively first and second relationships between the fluid pressure differential between said portions of said main conduit and the quantity flow of fluid per unit of time therethru, passage means arranged for flow parallel to said branch conduits, a single valve in said passage means subject to said fluid pressure differential, said differential acting on said single valve in an opening sense, spring means biasing said single valve to closed position, and means effective upon movement of said selector valve from said first to said second positions to vary in a valve-opening sense a force acting on said single valve, so that said single valve opens when said selector valve is in said first position at a first predetermined value of said pressure differential and when said selector valve is in said second position at a second lower value of said pressure differential.

19. A fuel supply system for an internal combustion engine, comprising a conduit for fuel flowing toward said engine, metering restriction means in said conduit, means for controlling the fuel pressure differential across said metering restriction means to regulate the flow of fuel therethru, enrichment valve means for varying the area of said restriction means, and operating means for said enrichment valve means including a movable wall separating first and second expansible chambers, means for communicating to said first chamber the pressure in the intake manifold of said engine, means for communicating to said second chamber the fuel pressure on the upstream side of said enrichment valve means, said wall being associated with said valve means so that movement of said wall accompanying an increase in pressure in said first chamber causes an opening movement of said enrichment valve means.

20. A fuel supply system for an internal combustion engine, comprising a conduit for combustion air flowing to said engine, a throttle in said conduit, a conduit for fuel flowing to said engine, metering restriction means in said fuel conduit, means responsive to the rate of flow of combustion air to said engine for controlling the fuel pressure differential across said metering restriction means to regulate the flow of fuel therethru, first enrichment valve means responsive to said fuel pressure differential for varying the area of said restriction means, first spring means biasing said first enrichment valve means closed and effective to hold said first valve means closed until said fuel pressure differential exceeds a predetermined value, second enrichment valve means responsive to the pressure in said air conduit downstream from said throttle for varying the area of said restriction means, and second spring means biasing said second enrichment valve means closed and effective to hold said second valve means closed until said air conduit pressure exceeds a predetermined value.

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