

Dec. 9, 1947.

J. M. BARR

2,432,274

CARBURETOR

Filed Oct. 21, 1944

5 Sheets-Sheet 2

Fig. 5

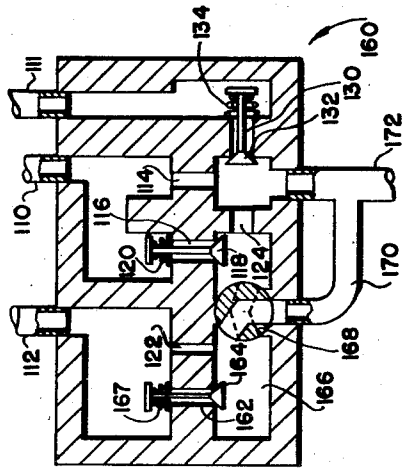


Fig. 4

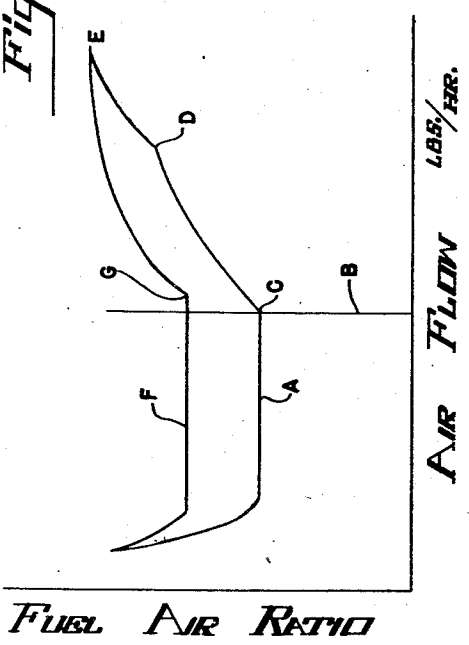
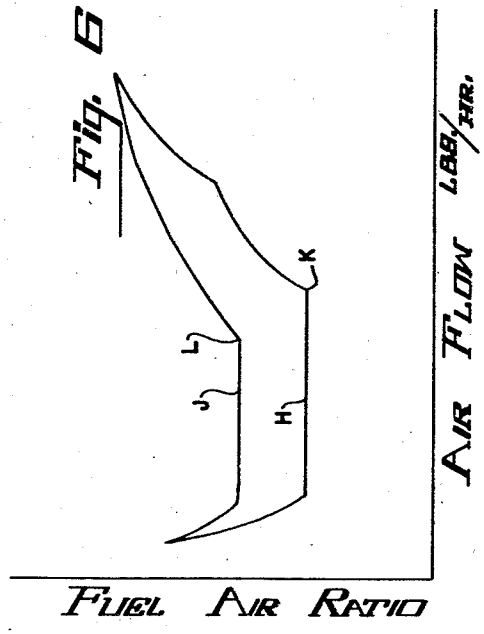


Fig. 6



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Filed Oct. 21, 1944

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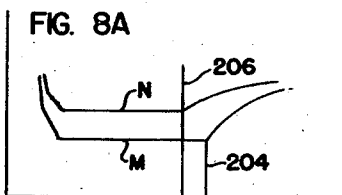
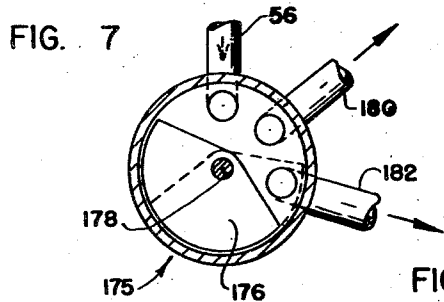


FIG. 8

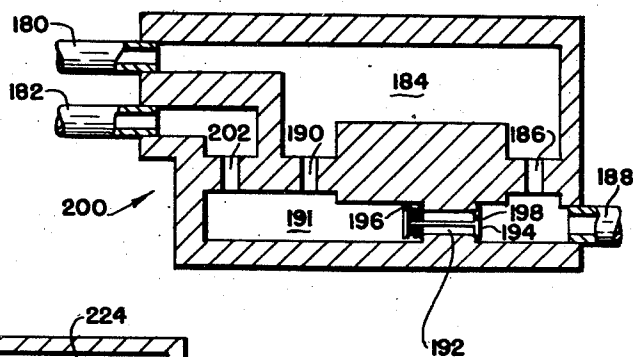


FIG. 9

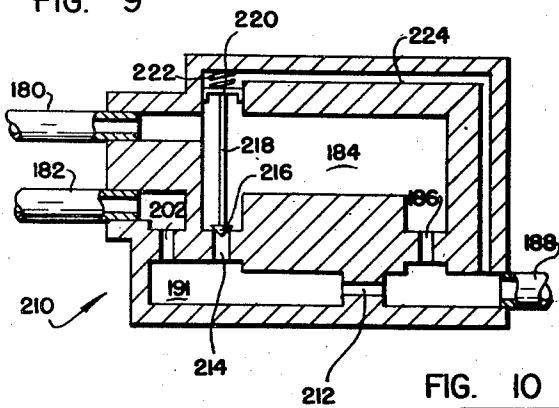
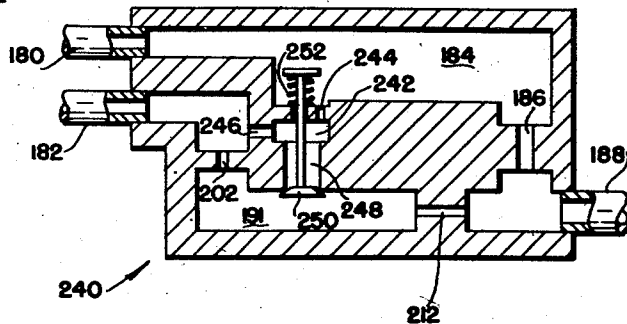


FIG. 10



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Filed Oct. 21, 1944

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FIG. 11

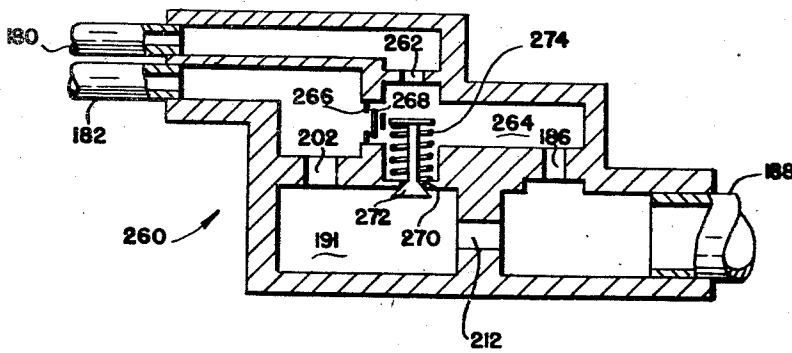
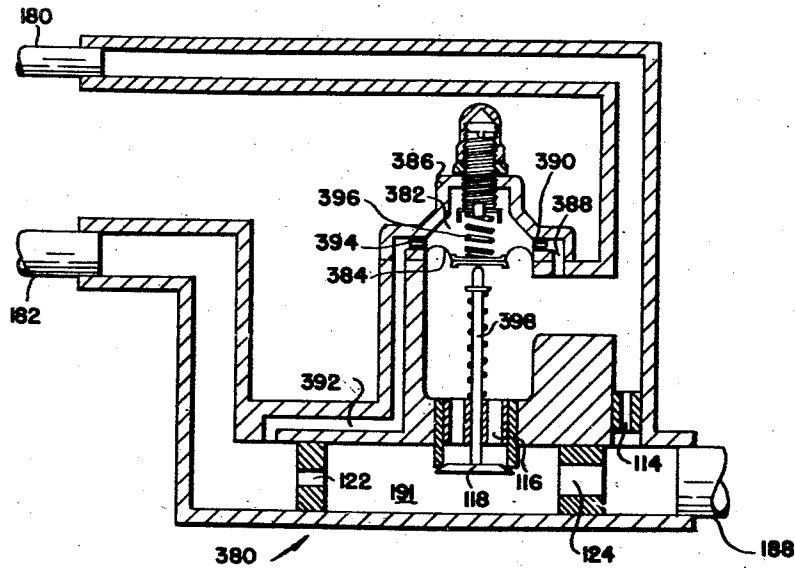


FIG. 14



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Filed Oct. 21, 1944

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FIG. 12

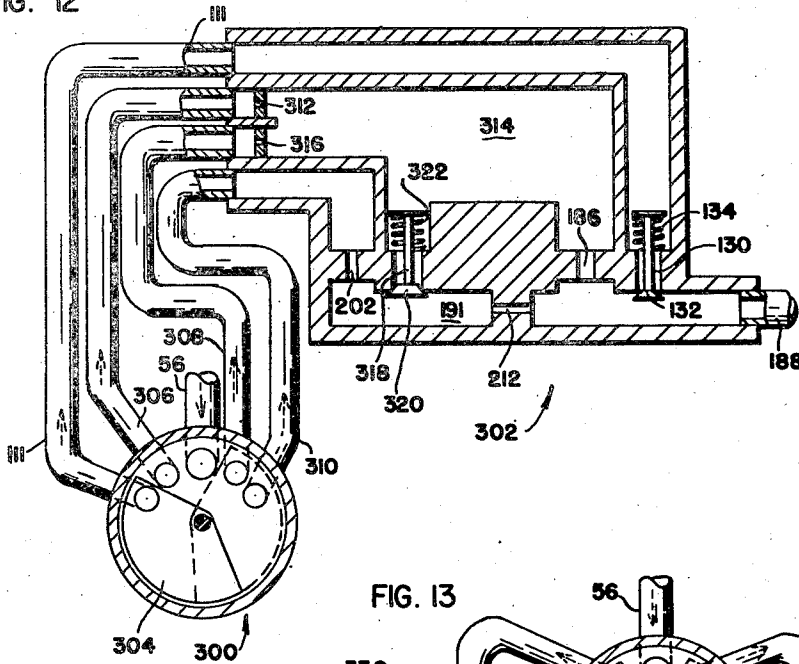
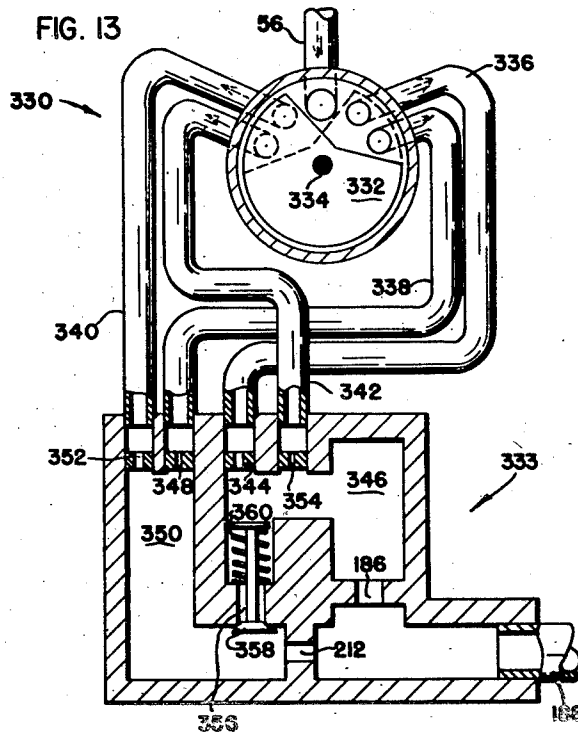


FIG. 13



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UNITED STATES PATENT OFFICE

2,432,274

CARBURETOR

John M. Barr, Meriden, Conn., assignor, by mesne assignments, to Niles-Bement-Pond Company, West Hartford, Conn., a corporation of New Jersey

Application October 21, 1944, Serial No. 559,766

14 Claims. (Cl. 261-41)

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The present invention relates to carburetors for internal combustion engines, and particularly to means for controlling the fuel-to-air ratio in such carburetors.

Modern carburetors for use on aircraft engines are usually provided with a manual control device whereby the pilot or some other member of the aircraft crew may select either a rich or lean fuel-to-air ratio. The usual practice is for the pilot to select a rich fuel-to-air ratio under conditions of high power output, such as take-off or combat conditions, and to select the lean fuel-to-air ratio under normal flight conditions in order to conserve the supply of fuel. The rich fuel-to-air ratio is also selected under adverse engine cooling conditions, since an engine runs cooler with a rich mixture than with a lean mixture.

It is desirable under maximum power output conditions to use a predetermined fuel-to-air ratio which is the best under those conditions, and to use that ratio regardless of the position in which the manual control is placed. It is, therefore, desirable to provide some means which sets the fuel-to-air ratio at a predetermined value at maximum power output.

It is customary to provide means for enriching the mixture of fuel and air when the load on the engine exceeds a predetermined value, regardless of the position in which the manual control is set. It has been suggested, in the co-pending application of Scott F. Hunt, Serial No. 498,151, filed August 11, 1943, to provide means whereby the enrichment of the fuel and air mixture takes place at different values of engine load when the manual mixture control is in its different positions.

It is therefore an object of the present invention to provide a carburetor including a manual control by which a lean fuel-to-air ratio or a rich fuel-to-air ratio may be selected, and improved means which operates when the load on the engine exceeds a predetermined value to provide a definite predetermined fuel-to-air ratio regardless of the position of the manual control.

Another object of this invention is to provide an improved mixture control device of the type shown in the co-pending application of Scott F. Hunt, previously referred to.

Another object of the invention is to provide a carburetor including a manual control for selecting a lean or rich fuel-to-air ratio, an enrichment control for increasing the fuel-to-air ratio at a predetermined value of engine load, and improved means for causing the enrichment control to operate at different values of engine load when the manual control is in its different positions.

A further object of the present invention is to provide a carburetor including manual control selectively movable to positions corresponding to lean and rich fuel-to-air ratios, enrichment con-

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trol means for increasing the fuel-to-air ratio at different predetermined values of engine load depending upon the position of the manual control, and means for establishing a predetermined value for the fuel-to-air ratio at maximum engine load regardless of the position of the manual control.

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 illustrates, somewhat diagrammatically, a carburetor for an aircraft type internal combustion engine including a mixture control and jet system built in accordance with the principles of my invention,

Figures 2 and 3 illustrate two different positions of a mixture control valve mechanism used in the carburetor of Figure 1,

Figure 4 is a graphical illustration of fuel-to-air ratio characteristics which are obtainable with the carburetor of Figure 1,

Figure 5 illustrates a modified form of jet system which may be used with the carburetor of Figure 1,

Figure 6 illustrates graphically certain fuel-to-air ratio characteristics which may be obtained by the use of the jet system of Figure 5,

Figure 7 illustrates a mixture control valve mechanism which may be used in place of the mixture control valve mechanism of Figure 1 when any of the jet systems shown in Figures 8, 9, 10, 11 and 14 are used in place of the jet system of Figure 1,

Figures 8, 9, 10, 11 and 14 illustrate modified forms of jet systems utilizing the principles of my invention, which may be used in place of the jet system of Figure 1, and

Figures 12 and 13 illustrate modified forms of mixture control valve mechanisms and jet systems which may be used in place of the corresponding elements of Figure 1.

Figure 1

Referring to the drawing, there is shown a body 10 of a carburetor for an internal combustion engine of an aircraft. Air enters the carburetor body 10 at an inlet 12 and flows thru a Venturi restriction 14 and a passage 15, past a throttle 16 and a fuel discharge nozzle 18 to an outlet 20. A supercharger may be provided between the outlet 20 and the intake manifold of the engine. In certain cases the supercharger may be upstream from the inlet 12, or two superchargers may be used, one in each place.

The Venturi restriction 14 produces a pressure differential between the inlet 12 and the throat of the restriction which varies substantially in accordance with the square of the velocity of the air passing thru the restriction. Since the cross-sectional area of the venturi is constant, this

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pressure differential may be taken as a measure of the volume of air flowing thru the passage per unit time.

In order to obtain a pressure differential varying as a function of the mass of air per unit time flowing thru the venturi 14, the pressure differential between entrance 12 and the throat of venturi 14 is utilized to create an air flow thru a secondary air passage extending from entrance 12 to the throat of venturi 14. A plurality of impact tubes 22 are provided, whose open ends project into the entrance 12 to receive the impact of the entering air. The secondary air passage may be traced from entrance 12, thru tubes 22, a passage 24 interconnecting the impact tubes, a conduit 26, a chamber 28 in a pressure meter generally indicated at 30, a restriction 32, a chamber 34 in the fuel meter 30, a conduit 36, past a valve 38 into a chamber 40, and thence thru a conduit 42 to the throat of venturi 14.

The valve 38 is operated by a sealed bellows 44 mounted in the chamber 40. The bellows 44 is fixed at one end, so that the position of the free end, to which valve 38 is attached, varies in accordance with the air pressure in the chamber 40. The bellows 44 is preferably filled with nitrogen or some other suitable temperature responsive fluid, so that the position of valve 38 varies not only with the pressure but with the temperature of the air in the chamber 40, and hence with the density of that air.

In the secondary air passage, the pressure differential between the entrance 12 and the throat of venturi 14 is divided into two component pressure drops, one across the restriction 32 and the other across the valve 38. The valve 38 is positioned in accordance with the density of the air flowing thru the passage 15. Valve 38 is moved toward open position as the air density increases and toward closed position as the air density decreases. If the volume of air flowing per unit time thru passage 15 remains constant while its density decreases, then the mass of air is decreased, but the pressure differential set up by the venturi 14 remains constant. However, the movement of valve 38 toward closed position causes the component pressure drop across valve 38 to increase, and the component pressure drop across restriction 32 to decrease, reflecting the decrease in the mass of air flowing. By proper design of valve 38, the pressure drop across restriction 32 may be made to vary substantially in accordance with the mass of air flowing thru passage 15.

This pressure differential across restriction 32 acts on a diaphragm 46 which separates the chambers 28 and 34. The force applied to diaphragm 46 is transmitted to a valve 52, on which it acts in an opening direction.

The fuel enters the carburetor from a fuel pump or other source of fuel under superatmospheric pressure. It flows thru a conduit 50, a valve 52 in the fuel meter 30, a chamber 82, a conduit 56, a mixture control valve mechanism generally indicated at 58, a jet system 60, an idle valve 125, a conduit 62, a valve 64 in a pressure regulator 66, and a conduit 68 to the fuel discharge nozzle 18.

The fuel meter 30 includes a diaphragm 86 separating chamber 34 from chamber 82 and a diaphragm 88 separating chamber 28 from a chamber 90. A spring 92 biases the valve 52 toward open position.

The chamber 90 is connected thru a conduit 94 to the fuel conduit 62 downstream from the jet system 60. The pressure in chamber 82 is

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the same as that in the fuel line upstream from the jet system. For any given constant cross-sectional area of the fuel passages thru the jet system 60, the pressure differential across it is a measure of the fuel flow thru it. This pressure differential is applied thru diaphragms 86 and 88 of the fuel meter 30 to the valve 52, on which it acts in a closing direction.

From the foregoing, it may be seen that the valve 52 is positioned in accordance with the balance between two forces, one of which varies in accordance with the mass of air entering the carburetor, and the other in accordance with the mass of fuel entering the carburetor. The valve 52 controls the pressure on the upstream side of the jet system 60. The pressure on the downstream side of the jet system is maintained substantially constant by the regulator 66, and therefore it may be stated that the valve 52 controls the pressure differential across the jet system. The valve 52 controls the pressure differential across the jet system in a manner to balance the fuel pressure differential against the air pressure differential acting on diaphragm 46. If the air and fuel pressure differentials are not balanced, the valve 52 is moved in a direction to restore a condition of balance.

The pressure regulator 66 includes a pair of expansible chambers 96 and 98 separated by a flexible diaphragm 100, which is attached at its center to the valve 64. A spring 102 biases the valve 64 toward closed position. The chamber 96 is connected thru a conduit 104 to the conduit 26 and thence thru the passage 24 and impact tubes 22 to the air entrance 12. The chamber 98 is connected to the conduit 62.

The mixture control valve mechanism 58 includes a disc valve 106 fixed on a shaft 108. The valve 106 controls the flow of fuel thru ports opening into conduits 110, 111 and 112, which lead into the jet system 60. When the valve 106 is in the position shown in Figure 1, fuel can flow thru both the conduits 110 and 112. This is known as the "rich" position of the mixture control valve mechanism. When the valve 106 is in the position shown in Figure 2, the fuel can flow thru conduits 110 and 111. This is known as the "lean" position of the valve mechanism 58. When the valve 106 is in the position shown in Figure 3, fuel cannot flow thru any of the conduits. This is known as the "cut-off" position of the mixture control valve mechanism 58.

The conduit 110 conducts the fuel either thru a fixed restriction or jet 114, or thru a restriction 116 controlled by an enrichment valve 118 biased to closed position by a spring 120. The conduit 112 conducts fuel to a fixed restriction 122. Fuel flowing thru the restrictions 116 and 122 also flows thru another restriction 124.

Fuel flowing thru the conduit 111 passes thru a restriction 130 controlled by an enrichment valve 132 which is biased to closed position by a spring 134.

Operation of Figure 1

As previously pointed out, the fuel meter 30 controls the fuel pressure differential across the mixture control 58 and the jet system 60 in proportion to the rate of flow of air thru the air passage 15. When the valve mechanism 58 is in the position illustrated in Figure 2, the only restrictions in the jet system thru which the fuel may flow are the restrictions 114, 116 and 130. Of these, the restrictions 116 and 130 are closed by the valves 118 and 132, respectively. Under these conditions, the variation of the fuel-to-air

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ratio with changes in air flow is that illustrated by the curve A in Figure 4. At intermediate values of air flow, the fuel-to-air ratio is substantially constant, since the only restriction open to the flow of fuel is the fixed restriction 114. When the air flow exceeds a value indicated by the abscissa B in Figure 4, the fuel pressure differential increases to a point where it overcomes the spring 120 and opens valve 118. The opening of valve 118 steadily increases as the air flow increases beyond this value, resulting in a variation of the fuel-to-air ratio as indicated between the points C and D in Figure 4. When the air flow reaches a value equivalent to the abscissa at point D, the fuel pressure differential becomes large enough to overcome spring 134 and open valve 132. The fuel-to-air ratio then follows the curve illustrated between the points D and E of Figure 4. The point E corresponds to maximum power output, or take-off conditions.

When the mixture control valve mechanism 53 is in the position illustrated in Figure 1, the fuel-to-air ratio varies with the air flow as illustrated by the characteristic F in Figure 4. At intermediate values of air flow, both the fixed restrictions 114 and 122 are open, so that the constant value of the fuel-to-air ratio is greater than that obtained when only the restriction 114 is open. When the air flow reaches the value indicated by abscissa B, the pressure drop across the valve 118 is slightly less than the total fuel pressure differential, due to the pressure drop thru restriction 124. Therefore, the valve 118 does not open until the air flow reaches a slightly higher value, as indicated at G. After valve 118 opens, the fuel-to-air ratio then increases along the curve illustrated between the points G and E. The restriction 124 is provided to limit the maximum rate of fuel flow which may take place thru the restrictions 116 and 122, when both are open. The restriction 124 is larger than either of the restrictions 116 and 122 alone, and, therefore, has little or no limiting action when only one of those two restrictions is open. When both are open, however, it tends to limit the maximum flow, and causes the flattening out observed near the right end of the curve between the points G and E of Figure 4.

At 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 air flow. Provision is made to control the fuel flow in accordance with the throttle position at such times. The spring 92 in fuel meter 30 acts on the valve 52 in an opening direction. When the differential pressure acting on diaphragm 46 is small, as under low air flow conditions, the spring 92 becomes the predominating force acting on valve 52. The valve 52, therefore, tends to open, increasing the pressure differential across the jet system beyond that which would be produced if the fuel pressure differential were maintained proportional to the air flow.

The idle valve 125 is pivotally attached to a lever 126, whose opposite end is connected by a link 127 to an arm 128 fixed on the shaft 129 of throttle 16. The idle valve is normally wide open when the throttle is beyond the idling range of positions, near its closed position. As the throttle moves into the idling range, the idle valve 125 moves toward closed position. At the same time, the spring 92 produces an opening movement of valve 52. The valve 52 is opened sufficiently so that its restrictive effect on the fuel flow is less

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than that of the idle valve 125. Therefore, the fuel flow under idling conditions is controlled primarily by the valve 125 in accordance with the throttle position, rather than by the pressure meter 30, in accordance with the mass of air entering the engine. The idle valve 125 is contoured so as to cause the enrichment of the fuel-to-air ratio illustrated at the left end of the curves A and F in Figure 4.

Figure 5

There is illustrated in Figure 5 in modified form a jet system generally indicated at 160, which may be used in place of the jet system 63 of Figure 1. In Figure 5, the parts of the system which are the same as the corresponding parts of Figure 1 have been given the same reference characters. Generally speaking, the restrictions fed by the conduits 110 and 111 are the same as the corresponding restrictions in passages of Figure 1. The restriction 122, however, has in parallel with it a restriction 162 controlled by an enrichment valve 164 biased to closed position by a spring 167. The restrictions 122 and 162 deliver fuel into a chamber 166 which is connected thru a valve 163 and a conduit 170 to a jet system outlet conduit 172. The valve 168 is of a rotatable cylindrical type, and is movable to a position wherein the fuel discharged from chamber 166 passes thru the restriction 124 instead of passing thru conduit 170 to the conduit 172.

When the valve 168 is in the position shown in full lines in the drawing, the fuel-to-air ratio characteristics obtained are those illustrated in Figure 6. The curve H in Figure 5 illustrates the characteristic obtained when the mixture control valve mechanism is in its "lean" position, as illustrated in Figure 2. Only the conduits 110 and 111 are then open to the flow of fuel. It should be noted that the curve H of Figure 5 is generally similar to the curve A of Figure 4. The various elements cooperate in the same way to produce the curve H of Figure 6 as they did to produce the curve A of Figure 4, and it is believed that further discussion of this particular characteristic is unnecessary.

When the mixture control valve mechanism 58 is moved to the position illustrated in Figure 1, however, the fuel-to-air ratio characteristic follows the curve J of Figure 6. It should be noted that the curve J starts to rise at an abscissa L, which is substantially to the left of the abscissa K where the curve H starts to rise. This difference is caused by the design of spring 167, which is weaker than spring 120, and therefore allows its associated valve to open at a lower fuel pressure differential than that at which valve 118 opens.

When the valve 168 is rotated to the position illustrated in dotted lines in the drawing, the characteristics obtained are the same as those illustrated in 156, except that the curve J flattens out more quickly at its right end.

Figures 7 and 8

There is illustrated in Figure 7 a mixture control valve mechanism 175, which may be used in place of the mixture control valve mechanism 58 of Figure 1 when one of the jet systems illustrated in Figures 8, 9, 10, 11 and 14 is used in place of the jet system 60 of Figure 1.

The mixture control valve mechanism 175 includes a disc valve 176 fixed on a rotatable shaft 178. The valve 176 controls the flow of fuel from a conduit 56, which may be the conduit 53 of

Figure 1, into a pair of fuel inlet passages 180 and 182. The valve 176 is shown in full lines in its "rich" position, in which both conduits 180 and 182 are open. The valve 176 is shown in dotted lines in its "lean" position, wherein only the conduit 180 is open.

Fuel entering the jet system 200 of Figure 8 thru conduit 180 passes into a chamber 184, and then may flow either thru a fixed restriction 186 to an outlet passage 188 or thru a fixed restriction 190 in series with a variable restriction 192. The restriction 192 is controlled by a valve 194 which is moved in an opening direction by the pressure drop across the valve, and biased to closed position by a spring 196. The valve 194 is provided with a small fixed orifice 198, which is not closed when the valve 194 rests on its seat.

Fuel entering the jet system 200 thru passage 182 passes thru a fixed restriction 202 into the chamber 191.

The fuel-to-air ratio characteristics obtained with the jet system of Figure 8 are illustrated in Figure 8A. When the valve mechanism 175 is in its "lean" position, the fuel-to-air ratio follows the curve M. When the valve mechanism 175 is in its "rich" position, the fuel-to-air ratio follows the curve N. The valve 194 is an enrichment valve, and it will be noted from a comparison of curves M and N of Figure 8A that valve 194 opens at a higher air flow indicated by the abscissa 204 when the valve mechanism 175 is in its "lean" position, and at lower value of air flow indicated by the abscissa 206 when the valve mechanism 175 is in its "rich" position. The difference between these two abscissas is determined by the design of the restrictions 198 and 202.

When the mixture control is in its "lean" position, the total fuel pressure differential across the jet system is applied across the restrictions 190 and 198 in series. The total fuel pressure differential may be considered as being separated into two component pressure drops, one across restriction 190 and the other across restriction 198. The relative magnitudes of these two pressure drops are in inverse proportion to the cross-sectional areas of the two restrictions. The pressure drop across restriction 198 is some predetermined proportion of the total fuel pressure differential. The valve 194 opens when the total fuel pressure differential increases to a point where this proportion is great enough to overcome spring 196.

When both inlet passages 180 and 182 are open, the pressure in the chamber 191 is increased, since it is now connected to the upstream side of the jet system thru the two parallel restrictions 190 and 202. Therefore, the pressure drop across valve 192 is now a greater proportion of the total fuel pressure differential than it was when the fuel inlet passage 182 was closed. Consequently, the pressure drop across restriction 198 now becomes sufficient to overcome spring 196 at a lower value of total fuel pressure differential than was the case under the previous conditions.

Figure 9

There is illustrated in Figure 9 a jet system 210, by which the same fuel-to-air ratio characteristics may be obtained as those obtained by the jet system 200 of Figure 8. In Figure 9, the fixed restrictions 186 and 202 are the same as the corresponding restrictions of Figure 8. The variable

restriction 192 of Figure 8 is replaced by a fixed restriction 212, and the fixed restriction 190 of Figure 8 is replaced by a variable restriction 214 controlled by a valve 216. The valve 216 is attached to a stem 218 whose upper end is attached to a piston 220. A spring 222 above the piston 220 biases the valve 216 to closed position. The chamber on the upper side of piston 220 is connected thru a passage 224 to the outlet of the jet system.

The total fuel pressure differential across the jet system acts in a valve opening direction on the piston 220, and is opposed by the spring 222 and by the pressure drop across valve 216 acting on the area of that valve, which is smaller than the area of piston 220. When the inlet passage 182 is closed, the pressure drop across valve 216, when closed, is the same as the total fuel pressure differential, because there is no flow, and hence no pressure drop, thru restriction 212. Therefore, when the total fuel pressure differential exceeds a value determined by the relative areas of piston 220 and valve 216, and also by the strength of spring 222, the spring is compressed and the valve opens.

When the inlet passage 182 is open, the pressure drops across valve 216 is less than the total fuel pressure differential by the amount of the pressure drop across restriction 212. Therefore, the force holding the valve 216 closed is smaller and consequently it opens at a lower value of fuel pressure differential than is the case when the inlet passage 182 is closed.

Figure 10

There is illustrated in Figure 10 a jet system 240 which may be used in place of the jet systems shown in Figures 8 and 9, and which produces the same fuel-to-air ratio characteristics which are illustrated in Figure 8A.

In the jet system 240, the restrictions 186, 202 and 212 are the same as the corresponding restrictions of Figure 9. The inlet and outlet passages are also the same and have been given corresponding reference characters. There is also provided in the jet system 240 a chamber 242 connected to the inlet chamber 184 by a restriction 244 and connected to the inlet passage 182 by a restriction 246. Fuel may be discharged from the chamber 242 thru a restricted passage 248 controlled by a valve 250, which is biased to closed position by a spring 252.

When fuel inlet passage 182 is closed, fuel flows from inlet passage 180 either directly thru restriction 186 to outlet passage 188 or thru restriction 244, chamber 242, restriction 246, restriction 202, chamber 191, and restriction 212 to outlet passage 188. Under these conditions, the pressure drop which acts on valve 250 in an opening direction is a predetermined proportion of the total pressure differential. This proportion was established by the relative areas of the restrictions 244, 246, 202 and 212.

When the inlet passage 182 is open, both restrictions 244 and 246 serve as inlets to the chamber 242, thereby increasing the pressure in that chamber and increasing the proportionality between the pressure drop across valve 250 and the total fuel pressure differential. The valve 250 is then opened at a smaller value of fuel pressure differential than in the previous case.

Figure 11

The jet system 260 illustrated in Figure 11 includes restrictions 186, 212 and 202, which are

substantially the same as the corresponding restrictions of Figure 10. In Figure 11, the inlet passage 180 supplies fuel directly to a restriction 262. The restriction 262 opens into a chamber 264. The chamber 264 is connected thru a restriction 266 to the inlet passage 182. A check valve 268 closes the restriction 266 whenever the pressure in chamber 264 is higher than that in inlet passage 182. A restricted passage 270 leads from chamber 264 into chamber 191. The passage 270 is controlled by a valve 272 biased to closed position by a spring 274.

When the inlet passage 182 is closed, the check valve 268 closes restriction 266, and the pressure drop acting in an opening direction on valve 272 is some predetermined proportion of the total fuel pressure differential which is established by the relative magnitudes of restrictions 262 and 186. When the inlet passage 182 is also open, the check valve 268 opens and increases the pressure in chamber 264, while the pressure on the downstream side of valve 272 remains substantially the same. Therefore, the pressure drop across the valve 272 is now a greater proportion of the total fuel pressure differential than was the case previously and, therefore, the valve 272 opens at a lower value of the total fuel pressure differential.

Figure 12

There is shown in Figure 12 a mixture control valve mechanism 300 and a jet system 332, which may be used in place of the corresponding elements of Figure 1. The arrangements shown in Figure 12 provide a set of fuel-to-air ratio characteristics similar to those shown in Figure 6. In the jet system of Figure 12, the inlet passage 111 and the valve 132 correspond to the elements bearing the same reference characters in Figure 1, and the function of these elements is the same.

The valve mechanism 300 includes a disc valve 304 which controls ports leading to inlet passages 111, 306, 308 and 310. When the disc 304 is in its "rich" position, shown in full lines in the drawing, the three inlet passages 306, 308 and 310 are all open. When the valve 304 is in its "lean" position, shown in dotted lines in the drawing, the inlet passages 306 and 111 are open.

In the jet system 302, the jets or restrictions 186, 202 and 212, and the chamber 191, function in the same manner as the corresponding elements of Figure 9. Fuel entering the jet system thru the inlet passage 306 passes thru a fixed restriction 312 into a chamber 314. Fuel entering the jet system thru the inlet passage 308 passes thru a fixed restriction 316 into the chamber 314. Fuel entering the jet system thru the inlet passage 310 passes thru the fixed restriction 202 into the chamber 191. A restricted passage 318 connects the chambers 314 and 191, and is controlled by a valve 320 biased to closed position by a spring 322 and movable to open position by the pressure drop across the passage 318.

When the mixture control 300 is in its "lean" position, the inlet passages 308 and 310 are closed, and the pressure in chamber 191 is substantially the same as the outlet pressure of the jet system. The pressure drop across passage 318 is then determined by the relative sizes of the restrictions 312 and 186. When the mixture control is in its "rich" position, the inlet passage 308 leading thru restriction 316 is open and the pressure in chamber 314 is thereby increased. The pressure drop across valve 320 then becomes a

greater proportion of the total pressure differential across the jet system than was the case when only the inlet passages 306 and 111 were open. Therefore, the valve 320 opens at a lower value of fuel pressure differential.

Figure 13

There is shown in Figure 13 a mixture control valve mechanism 330 and a jet system 332, which may be used in place of the mixture control and jet system of Figure 1. In the jet system of Figure 13, the restrictions 186 and 212 correspond to the same restrictions in the previous figure.

The mixture control valve mechanism 330 includes a valve 332 attached to a shaft 334. When the valve 332 is in its "rich" position, shown in full lines in the drawing, two inlet passages 335 and 338 are open. When the valve 332 is in its "lean" position, shown in dotted lines in the drawing, two inlet passages 340 and 342 are open. The inlet passage 336 leads thru a restriction 344 into a chamber 346, and the inlet passage 338 leads thru a restriction 348 into a chamber 350. The inlet passage 340 leads thru a restriction 352 to the chamber 350, and the inlet passage 342 leads thru a restriction 354 to the chamber 346. The chamber 346 is connected thru the fixed restriction 186 to the outlet passage 188. The chamber 346 is also connected thru a passage 356 controlled by an enrichment valve 358 which is biased to closed position by a spring 360. The pressure drop thru the passage 356 acts on the valve 358 in an opening direction. The passage 356 leads into chamber 350, connected to the outlet passage 188 of the jet system by the restriction 212.

When the mixture control is in its "lean" position, the chamber 346 is fed thru the relatively small restriction 354, and the pressure drop across valve 358 is a certain predetermined proportion of the total fuel pressure differential, depending upon the relative sizes of restrictions 354 and 186. When the mixture control is in its "rich" position, the chamber 346 is fed thru the relatively large restriction 344, and the pressure in chamber 346 is, therefore, higher. Consequently, the pressure drop across valve 358 is now a greater proportion of the total fuel pressure differential than before, and the valve 358, therefore, opens at a lower value of the total pressure differential.

Figure 14

There is shown in Figure 14 a jet system 380, which may be used in place of the jet system 60 of Figure 1. The mixture control valve mechanism 175 of Figure 7 should be used with the jet system of Figure 14. The jet system of Figure 14 is similar to that of Figure 1 except that the restriction 130 and its associated control mechanism has been omitted and additional control mechanism is provided for the enrichment valve 118 in the restriction 116. This additional control mechanism consists of a chamber 382 formed between a diaphragm 384 and a cover 385 which is attached by any suitable means to the jet system. The chamber 382 is connected to the inlet passage 180 thru a branch passage 388 having the restriction 390 in it. The chamber 382 is connected to the inner passage 182 by branch passage 392 having a restriction 394 in it. A spring 396 biases the diaphragm 384 in a direction so that it tends to engage the end of the stem 398 of valve 118.

When the mixture control is in its "lean" position, fuel may flow from inlet passage 180 thru

passage 398, restriction 399, chamber 382, restriction 394, branch passage 392, restriction 122, chamber 181, and restriction 124 to outlet passage 188. The passage drop across diaphragm 384 acts in a direction to compress spring 396 and to maintain diaphragm 384 free of the end of valve stem 398. The particular value of total pressure differential at which valve 118 opens is then determined by the area of valve 118 and the strength of spring 120.

When the mixture control is in its "rich" position, both inlet passages 180 and 182 are open, and fuel may then enter chamber 382 thru either restriction 398 or 394. The pressure in chamber 382 is then substantially equal to the pressure in the inlet passages 180 and 182. There is then no pressure drop across the diaphragm 384 and the spring 396 moves the diaphragm 384 downwardly until it engages the end of valve stem 398. The force of spring 120 tending to hold valve 118 closed is then partially opposed by the force of spring 396 tending to open it. Therefore, it takes a smaller value of total pressure differential to open valve 118 and enrich the fuel flow.

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, comprising a conduit for fuel flowing to said engine, a jet system including a plurality of interconnected passages and restrictions in said conduit for regulating the flow of fuel therethru in accordance with the fuel pressure differential across said jet system, means for varying said fuel pressure differential, a chamber in said jet system, a passage including at least one of said restrictions connecting said chamber and said fuel conduit at one side of said jet system, second and third restrictions in parallel connecting said chamber and said fuel conduit at the other side of said jet system, a valve subject to the pressure in said chamber and adapted to be moved in an opening direction by said pressure for controlling one of said three restrictions, means biasing said valve to closed position, and valve means selectively movable between a first position wherein only one of said two parallel restrictions is open and a first predetermined relationship between said fuel pressure differential and the fuel flow thru said conduit is established and a second position wherein both said parallel restrictions are open and a second predetermined relationship between said fuel pressure differential and the fuel flow thru said conduit is established, said valve means being effective to vary the relationship between said pressure differential and the pressure in said chamber so that when said valve means is in said first position said valve opens when said fuel pressure differential exceeds a first predetermined value, and when said valve means is in said second position said valve opens when said fuel pressure differential exceeds a second predetermined value lower than said first predetermined value.

2. A fuel supply system for an internal combustion engine, comprising a conduit for fuel flowing to said engine, a jet system including a plurality of passages and restrictions in said conduit for regulating the flow of fuel therethru in accordance with the fuel pressure differential across said jet system, means for varying said fuel pressure differential, a chamber in said jet

system, a passage including at least one of said restrictions connecting said chamber and said fuel conduit at one side of said jet system, second and third restrictions in parallel connecting said chamber and said fuel conduit at the other side of said jet system, a valve in one of said three restrictions for controlling the flow of fuel therethru, said valve being subject to the pressure in said chamber and adapted to be moved in an opening direction by said pressure, means biasing said valve to closed position, and valve means selectively movable between a first position wherein only one of said two parallel restrictions is open and a first predetermined relationship between said fuel pressure differential and the fuel flow thru said conduit is established and a second position wherein both said parallel restrictions are open and a second predetermined relationship between said fuel pressure differential and the fuel flow thru said conduit is established, said valve means being effective to vary the relationship between said fuel pressure differential and the pressure differential which operates said valve so that when said valve means is in said first and second positions, said valve opens said one restriction when said fuel pressure differential exceeds first and second predetermined values, respectively.

3. A fuel supply system for an internal combustion engine, comprising a conduit for fuel flowing to said engine, a plurality of parallel restricted passages in said conduit for regulating the flow of fuel therethru in accordance with the fuel pressure differential across said passages, means for varying said fuel pressure differential, manually operable valve means for selectively opening said passages to the flow of fuel and movable between a first position wherein a first of said passages is open and a first predetermined value is established for the total cross-sectional area of the open passages and a second position wherein said first passage and a second passage are open and a second predetermined value greater than said first predetermined value is established for said total cross-sectional area, first means to increase said total cross-sectional area when said valve means is in said first position and said pressure differential exceeds a first predetermined value, second means to increase said total cross-sectional area when said valve means is in said second position and said pressure differential exceeds a second predetermined value lower than said first predetermined value, a third passage controlled by said manually operable valve means and opened thereby when said valve means is in said first position, a valve in said third passage and subject to said pressure differential acting thereon in an opening direction, a spring biasing said valve to closed position and effective to maintain said valve closed until said pressure differential exceeds a third predetermined value higher than said first and second predetermined values, said valve being effective when said manually operable valve means is in said first position and said pressure differential exceeds a fourth predetermined value greater than said third to increase said total area to an amount substantially equal to that obtained when said manually operable valve means is in said second position and said pressure differential exceeds said fourth predetermined value.

4. A fuel supply system for an internal combustion engine, comprising a conduit for fuel flowing to said engine, a jet system including a plurality of metering restrictions in said conduit

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for regulating the flow of fuel therethru in accordance with the fuel pressure differential across said jet system, means for varying said fuel pressure differential, a chamber in said jet system, at least one restricted passage connecting said chamber and said fuel conduit at one side of said jet system, second and third restricted passages in parallel connecting said chamber and said fuel conduit at the other side of said jet system, a valve responsive to the pressure differential across one of said three restricted passages for controlling the fuel flow therethru, means biasing said valve to closed position, valve means selectively movable between a first position wherein only one of said two parallel restricted passages is open and a first predetermined relationship between said fuel pressure differential and the fuel flow thru said conduit is established and a second position wherein both said parallel restricted passages are open and a second predetermined relationship between said fuel pressure differential and the fuel flow thru said conduit is established whereby a greater fuel flow is produced by a given pressure differential, said pressure responsive valve being effective when said valve means is in said first position to open said one restricted passage and increase the fuel flow produced by a given pressure differential when said fuel pressure differential exceeds a first predetermined value, and effective when said valve means is in said second position to open said one restricted passage when said fuel pressure differential exceeds a second predetermined value lower than said first predetermined value, and means effective when said valve means is in either of said first or second positions and said pressure differential exceeds a third value greater than said first and second values to produce a predetermined fuel flow.

5. A fuel supply system for an internal combustion engine, comprising a conduit for fuel flowing to said engine, a jet system including a plurality of metering restrictions in said conduit for regulating the flow of fuel therethru in accordance with the fuel pressure differential across said jet system, means for varying said fuel pressure differential, a chamber in said jet system, at least one restricted passage connecting said chamber and said fuel conduit at one side of said jet system, second and third restricted passages in parallel connecting said chamber and said fuel conduit at the other side of said jet system, a valve responsive to the pressure differential across said one restricted passage for controlling the fuel flow therethru, means biasing said valve to closed position, a fourth passage connecting the opposite sides of said jet system and including a fixed restriction, a fifth passage connecting the opposite sides of said jet system, a valve in said fifth passage subject to said fuel pressure differential acting thereon in an opening direction, a spring biasing said last-mentioned valve to closed position, and valve means selectively movable between a first position wherein said fifth passage and one of said two parallel restricted passages is open and a first predetermined relationship between said fuel pressure differential and the fuel flow thru said conduit is established and a second position wherein said fourth passage and both said parallel restricted passages are open and a second predetermined relationship between said fuel pressure differential and the fuel flow thru said conduit is established.

6. A fuel supply system for an internal combustion engine, comprising a conduit for fuel

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flowing to said engine, a jet system including a plurality of metering restrictions in said conduit for regulating the flow of fuel therethru in accordance with the fuel pressure differential across said jet system, means for varying said fuel pressure differential, a chamber in said jet system, at least one restricted passage connecting said chamber and said fuel conduit at one side of said jet system, second and third passages including restrictions of different sizes connected in parallel between said chamber and said fuel conduit at the other side of said jet system, a valve responsive to the pressure differential across said one restricted passage for controlling the fuel flow therethru, means biasing said valve to closed position, fourth and fifth passages connected in parallel between the opposite sides of said jet system and including restrictions of different sizes, and valve means selectively movable between a first position wherein the one of said second and third passages having the larger restriction and the one of said fourth and fifth passages having the smaller restriction are open and a first predetermined relationship between said fuel pressure differential and the fuel flow thru said conduit is established and a second position wherein the one of said second and third passages having the smaller restriction and the one of said fourth and fifth passages having the larger restriction are open and a second predetermined relationship between said fuel pressure differential and the fuel flow thru said conduit is established.

7. A fuel supply system for an internal combustion engine, comprising a conduit for fuel flowing to said engine, a jet system including a plurality of metering restrictions in said conduit for regulating the flow of fuel therethru in accordance with the fuel pressure differential across said jet system, means for varying said fuel pressure differential, a first passage extending thru said jet system and including two restrictions in series, a second passage extending thru said jet system and including two restrictions in series, a third passage extending from the upstream side of said jet system to said first passage at a point between the two restrictions therein and including a single restriction, a branch passage connecting said point in said first passage with a point in said second passage between the two restrictions therein, a valve in said branch passage movable in an opening direction by the pressure drop between the ends of said branch passage, a spring biasing said valve to closed position and effective to maintain said valve closed until said pressure drop exceeds a predetermined value, and valve means for controlling the inlets to said first, second and third passages and selectively movable between a first position wherein only the inlet of said first passage is open, thereby establishing a first proportional relationship between said fuel pressure differential and said pressure drop, and a second position wherein the inlets of said first, second and third passages are all open, thereby establishing a second proportional relationship between said fuel pressure differential and said pressure drop, said pressure responsive valve being effective due to the difference in said relationships when said valve means is in said first and second positions to open said branch passage and increase the total fuel flow when said fuel pressure differential exceeds first and second predetermined values, respectively.

8. A fuel supply system for an internal combustion engine, comprising a conduit for fuel flowing to said engine, a jet system including a

plurality of metering restrictions in said conduit for regulating the flow of fuel therethru in accordance with the fuel pressure differential across said jet system, means for varying said fuel pressure differential, a first passage extending thru said jet system and including a single restriction, a second passage extending thru said jet system and including two restrictions in series, a chamber in said jet system, a first branch passage of limited capacity connecting said chamber and said first passage at the upstream side of the restriction therein, a second branch passage of limited capacity connecting said chamber and said second passage on the upstream side of the two restrictions therein, a third passage for delivering fuel into said second passage at a point between the two restrictions therein, a valve in said third passage movable in an opening direction by the pressure in said chamber, a spring biasing said valve to closed position, and valve means for controlling the inlets to said first and second passages and selectively movable between a first position wherein only the inlet of said first passage is open so that only said first branch passage acts as an inlet to said chamber, and a second position wherein the inlets of both said first and second passages are open so that both said first and second branch passages act as inlets to said chamber, said pressure responsive valve being effective due to the difference in the pressure in said chamber when said valve means is in said first and second positions to open said third passage and increase the total fuel flow when said fuel pressure differential exceeds first and second predetermined values, respectively.

9. A fuel supply system for an internal combustion engine, comprising a conduit for fuel flowing to said engine, a jet system including a plurality of interconnected passages and restrictions in said conduit for regulating the flow of fuel therethru in accordance with the fuel pressure differential across said jet system, means for varying said fuel pressure differential, first and second fuel inlet passages opening into said jet system from said conduit, a chamber in said jet system, a first one of said restrictions connecting said chamber and said first fuel inlet passage, a second of said restrictions connecting said chamber and said second fuel inlet passage, a third passage for delivering fuel to the outlet of said jet system, a valve in said third passage movable in an opening direction by the pressure in said chamber, a spring biasing said valve to closed position, and valve means for controlling said first and second fuel inlet passages and selectively movable between a first position wherein only said first inlet passage is open so that only said first restriction acts as an inlet to said chamber, and a second position wherein both said first and second fuel inlet passages are open so that both said first and second restrictions act as inlets to said chamber, said pressure responsive valve being effective due to the difference in the pressure in said chamber when said valve means is in said first and second positions to open said third passage and increase the total fuel flow when said fuel pressure differential exceeds first and second predetermined values, respectively.

10. A fuel supply system for an internal combustion engine, comprising a conduit for fuel flowing to said engine, a jet system including a plurality of interconnected passages and restrictions in said conduit for regulating the flow of

fuel therethru in accordance with the fuel pressure differential across said jet system, means for varying said fuel pressure differential, first and second fuel inlet passages opening into said jet system from said conduit, an expansible chamber in said jet system having a movable wall, a first one of said restrictions connecting said chamber and said first fuel inlet passage, a second of said restrictions connecting said chamber and said second fuel inlet passage, a third passage for delivering fuel to the outlet of said jet system, a valve in said third passage, a spring biasing said valve to closed position, means including said movable wall for opening said valve against said biasing means, and valve means for controlling said first and second fuel inlet passages and selectively movable between a first position wherein only said first inlet passage is open so that only said first restriction acts as an inlet to said chamber, and a second position wherein both said first and second fuel inlet passages are open so that both said first and second restrictions act as inlets to said chamber, said valve opening means being effective due to the difference in the pressure in said chamber when said valve means is in said first and second positions to open said third passage and increase the total fuel flow when said fuel pressure differential exceeds first and second predetermined values, respectively.

11. A fuel supply system for an internal combustion engine, comprising a conduit for fuel flowing to said engine, a jet system including a plurality of interconnected passages and restrictions in said conduit for regulating the flow of fuel therethru in accordance with the fuel pressure differential across said jet system, means for varying said fuel pressure differential, first and second fuel inlet passages opening into said jet system from said conduit, a chamber in said jet system, a first one of said restrictions connecting said chamber and said first fuel inlet passage, a second of said restrictions connecting said chamber and said second fuel inlet passage, a third passage including third and fourth restrictions in series connecting said second fuel inlet passage to the outlet of said jet system, a fourth passage for delivering fuel into said third passage at a point between said third and fourth restrictions, a valve in said fourth passage movable in an opening direction by the pressure in said chamber, a spring biasing said valve to closed position, and valve means for controlling said first and second fuel inlet passages and selectively movable between a first position wherein only said first inlet passage is open so that only said first restriction acts as an inlet to said chamber, and a second position wherein both said first and second fuel inlet passages are open so that both said first and second restrictions act as inlets to said chamber, said pressure responsive valve being effective due to the difference in the pressure in said chamber when said valve means is in said first and second positions to open said third passage and increase the total fuel flow when said fuel pressure differential exceeds first and second predetermined values, respectively.

12. A fuel supply system for an internal combustion engine, comprising a conduit for fuel flowing to said engine, a plurality of parallel restricted passages in said conduit for regulating the flow of fuel therethru in accordance with the fuel pressure differential across said passages, means for varying said fuel pressure differential,

manually operable valve means for selectively opening said passages to flow of fuel and movable between a first position wherein a first of said passages is open and a first predetermined value is established for the total cross-sectional area of the open passages and a second position wherein said first passage and a second passage are open and a second predetermined value greater than said first predetermined value is established for said total cross-sectional area, means to increase said total cross-sectional area when said valve means is in either of said first and second positions and said pressure differential exceeds a first predetermined value, a third passage controlled by said manually operable valve means and opened thereby when said valve means is in said first position, a valve in said third passage and subject to said pressure differential acting thereon in an opening direction, a spring biasing said valve to closed position and effective to maintain said valve closed until said pressure differential exceeds a second predetermined value higher than said first predetermined value, said valve being effective when said manually operable valve means is in said first position and said pressure differential exceeds a third predetermined value greater than said second to increase said total area to an amount substantially equal to that obtained when said manually operable valve means is in said second position and said pressure differential exceeds said third predetermined value.

13. A fuel supply system for an internal combustion engine, comprising a conduit for fuel flowing to said engine, a plurality of parallel restricted passages in said conduit for regulating the flow of fuel therethru in accordance with the fuel pressure differential across said passages, means for varying said fuel pressure differential, manually operable valve means for selectively opening said passages to the flow of fuel and movable between a first position wherein a first of said passages is open and a first predetermined value is established for the total cross-sectional area of the open passages and a second position wherein said first passage and a second passage are open and a second predetermined value greater than said first predetermined value is established for said total cross-sectional area, means to increase said total cross-sectional area when said valve means is in either of said first and second positions and said pressure differential exceeds a first predetermined value, a third passage, a valve in said third passage and subject to said pressure differential acting thereon in an opening direction, a spring biasing said valve to closed position and effective to maintain

said valve closed until said pressure differential exceeds a second predetermined value higher than said first predetermined value, said valve and said manually operable valve means cooperating to control said third passage so that when said manually operable valve means is in said first position and said pressure differential exceeds a third predetermined value greater than said second said total area is increased to an amount substantially equal to that obtained when said manually operable valve means is in said second position and said pressure differential exceeds said third predetermined value.

14. A fuel supply system for an internal combustion engine, comprising a conduit for fuel flowing to said engine, a jet system including a plurality of interconnected passages and restrictions in said conduit for regulating the flow of fuel therethru in accordance with the fuel pressure differential across said jet system, means for varying said fuel pressure differential, first and second fuel inlet passages opening into said jet system from said conduit, a chamber in said jet system, a first one of said restrictions connecting said chamber and said first fuel inlet passage, means connecting said chamber and said second fuel inlet passage, a third passage for delivering fuel to the outlet of said jet system, a valve in said third passage movable in an opening direction by the pressure in said chamber, a spring biasing said valve to closed position, and valve means for controlling said first and second fuel inlet passages and selectively movable between a first position wherein only said first inlet passage is open so that only said first restriction acts as an inlet to said chamber, and a second position wherein both said first and second fuel inlet passages are open so that both said first restriction and said connecting means act as inlets to said chamber, said pressure responsive valve being effective due to the difference in the pressure in said chamber when said valve means is in said first and second positions to open said third passage and increase the total fuel flow when said fuel pressure differential exceeds first and second predetermined values, respectively.

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