

Jan. 16, 1962

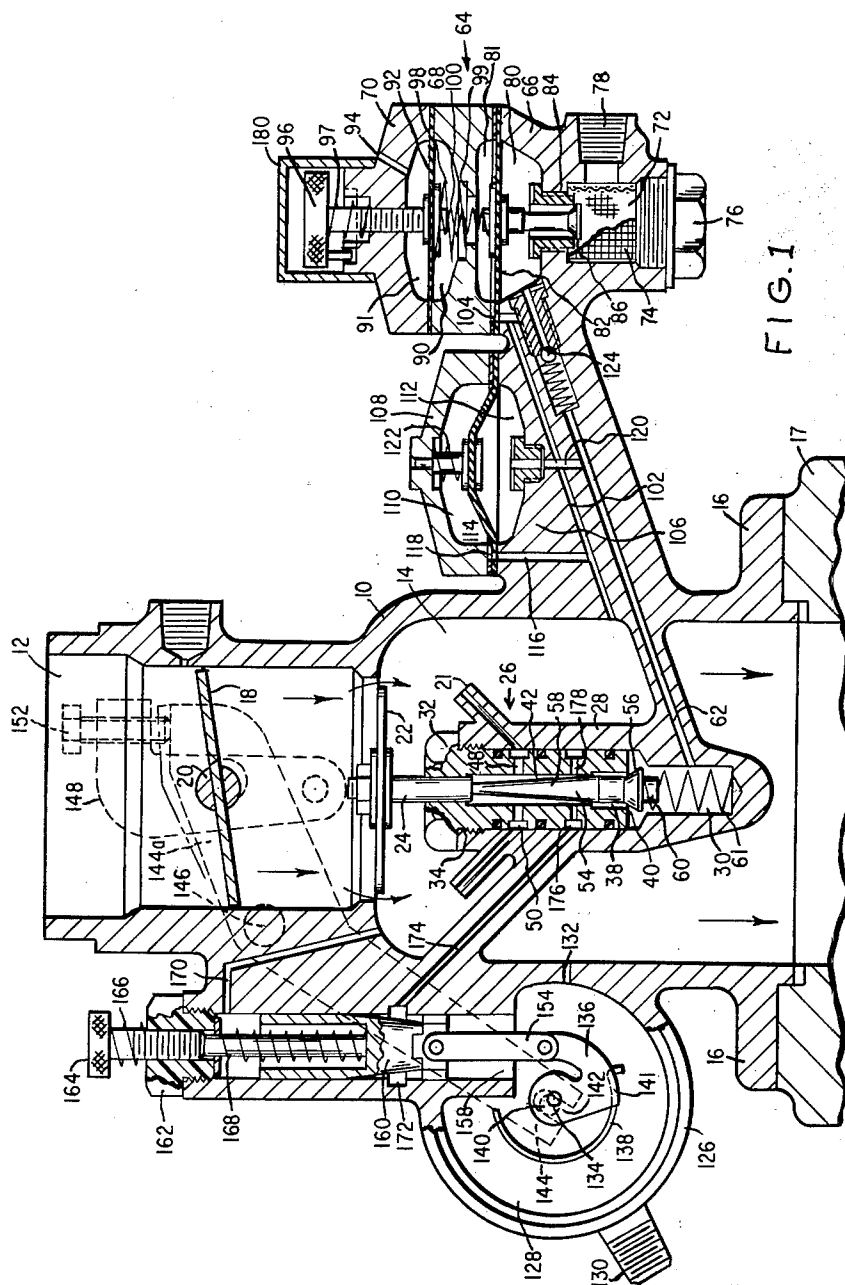
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3,016,889

FUEL INJECTOR

Filed July 8, 1958

3 Sheets-Sheet 1



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3 Sheets-Sheet 2

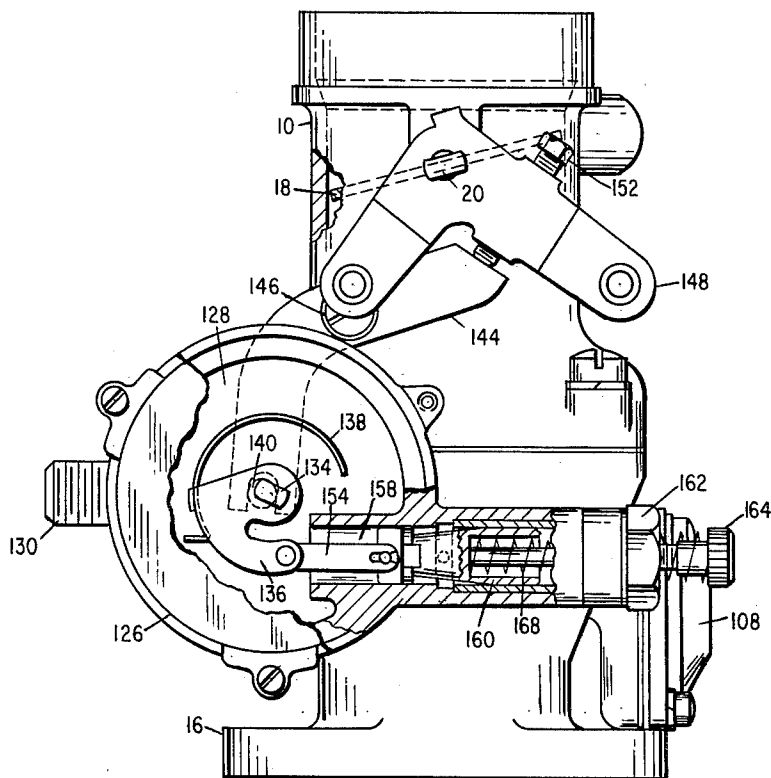


FIG. 2

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3 Sheets-Sheet 3

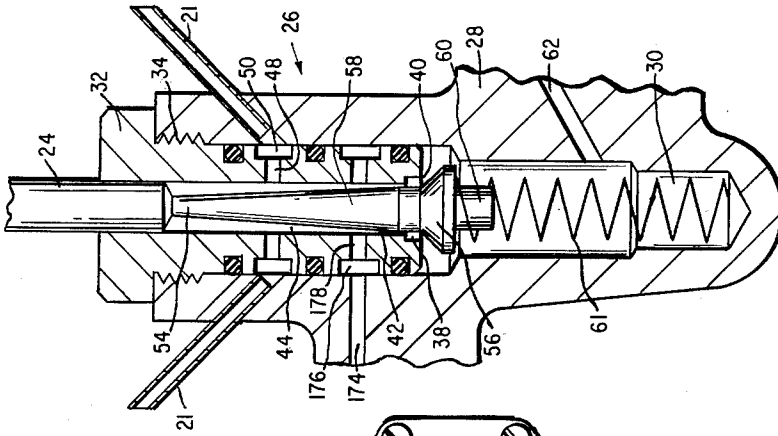


FIG. 4

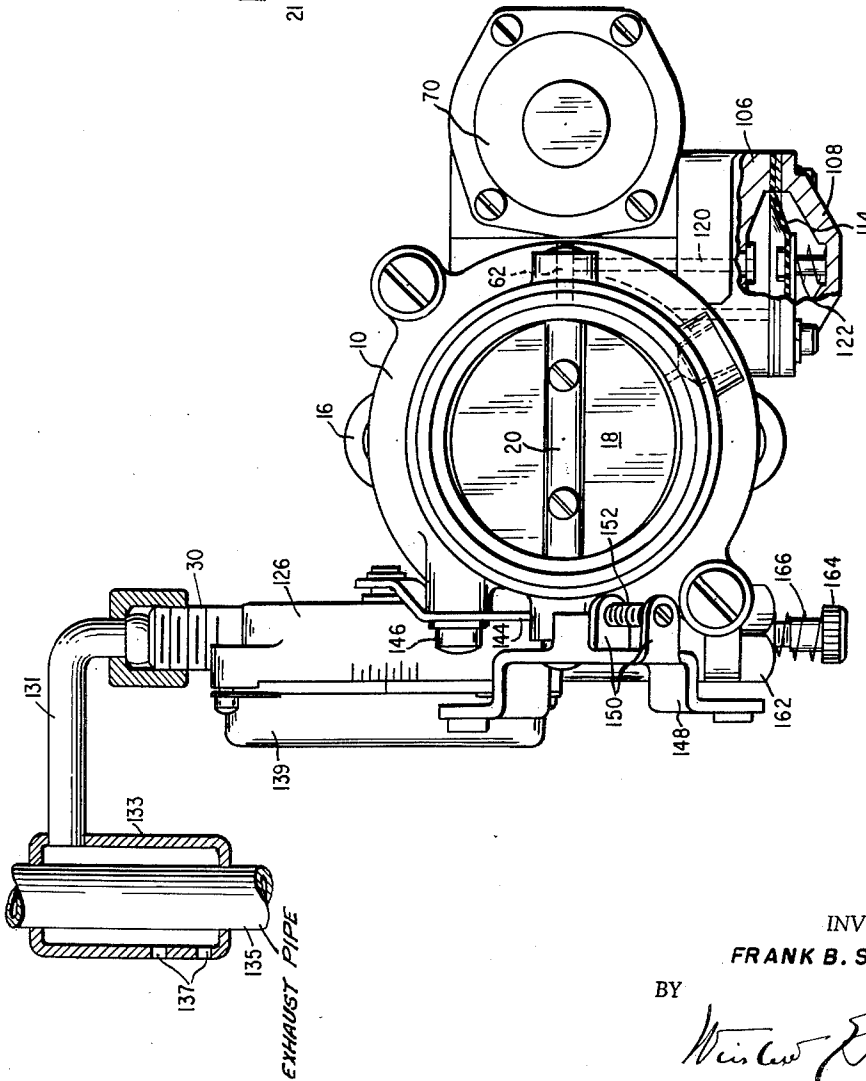


FIG. 3

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FUEL INJECTOR

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13 Claims. (Cl. 123—119)

This invention relates to fuel injectors, and more particularly to fuel injectors of the pressure injection type suitable for use with internal combustion engines of the gasoline type, one object being the provision of a more satisfactory injector of this description.

The purpose of fuel injectors is to provide an internal combustion engine with a suitable mixture of fuel and air, in the proper proportions for most efficient operation. However, due to the wide variety of operating conditions encountered by the modern internal combustion engine in automotive, aircraft, marine and other services, it is necessary that the composition and the amount of this fuel-air mixture be varied continuously in order to have the engine operate satisfactorily under all conditions. The provision of an injection apparatus which will automatically provide the necessary mixture of the correct composition and of correct quantity is another object of this invention.

Another object of my invention is to provide a fuel injection system in which the fuel and air are accurately metered under substantially all conditions of operation to the end that the proper ratio of fuel to air is supplied to the engine for optimum results substantially through the entire range of the engine.

Another object of my invention is to provide a fuel injection system wherein means are provided for automatically supplying a rich mixture of atomized fuel when the engine is started.

Another object of my invention is to provide a fuel injection system in which, under normal conditions of operation, fuel pressure at the fuel metering valve is maintained substantially constant.

Another object of my invention is to provide a pressure injection system wherein the air flowing to the engine governs the operation of the fuel metering means so that the ratio of fuel to air is maintained in the proper proportions for the best operation of the engine under normal conditions, and at the same time, provision is made for increasing the ratio of fuel to air automatically when the engine is operating under load conditions.

Another object of my invention is to provide means which will supply additional fuel during the initial stages of sudden rapid acceleration in order to provide a particularly rich mixture in order to allow the engine to accelerate rapidly and smoothly.

Another object of my invention is to provide a fuel injection system containing parts which automatically hold the throttle in a partially open condition when the engine is cold in order to provide for automatic fast idling until the engine has attained proper operating temperature.

A further object of my invention is to provide a fuel injection system in which the fuel is introduced into the air stream under pressure and by means of nozzles constructed and arranged to secure better atomization of the fuel, and wherein means are provided for increasing the turbulence of the air passing through the atomization zones in order to secure substantially uniform co-mingling of the fuel vapor and air for providing a more uniform fuel-air mixture for distribution to the cylinders.

A further object of my invention is to provide a simplified pressure injection mechanism which is economical in fuel consumption, simple in construction, positive and trouble free in operation.

Another object of my invention is the provision of a fuel injection system of the above description which is completely automatic in operation, in order to compensate for other factors of temperature, load, speed of operation,

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acceleration and deceleration and all other factors entering into engine operation so as to automatically provide the proper fuel-air mixture for all operating conditions.

Other objects and advantages of this invention will be particularly set forth in the claims and will be apparent from the following description, when taken in connection with the accompanying drawings, in which:

FIG. 1 is a schematic side-elevational, cross-sectional view illustrating the relationship and the functioning of the parts of this invention;

FIG. 2 is a side-elevational view, partially in section, of one embodiment of this invention;

FIG. 3 is a top plan view, partially in section, of the embodiment shown in FIG. 2; and

FIG. 4 is an enlarged fragmentary cross-sectional view of the fuel metering valve.

A fuel injection device embodying the present invention and herewith disclosed for purposes of illustration, preferably comprises a body portion 10 (FIG. 1), having an air intake passage 12 and a mixing chamber 14. Body portion 10 is preferably provided with suitable mounting flanges 16 adapted to be attached to the intake conduit or manifold 17 of an internal combustion engine. A throttle valve 18, preferably of the butterfly type, is mounted on a rotatable shaft 20 in air intake passage 12 for regulating the flow of air through mixing chamber 14.

Mixing chamber 14 contains a plurality of nozzles or fuel jets 21 for injecting atomized fuel into the air stream. Nozzles 21 are supplied with a measured amount of fuel by means of a metering valve shown generally at 26 in FIG. 1.

Valve 26 is actuated by the impingement of the air stream on a disc 22 mounted on a generally vertically extending rod 24 which forms an operative part of metering valve 26. Valve 26 is mounted in a vertically extending, generally cylindrical shaped housing 28 which may be conveniently formed as an integral part of body 10. Housing 28 is provided with a vertically extending central bore 30, the upper portion of which contains a metering valve body 32. Valve body 32 is preferably threadedly fastened in bore 30 as shown at 34 and is provided with an outwardly extending annular flange which overlies the top of valve casing 28.

Valve body 32 is provided with an axial cylindrical bore having a plurality of diameters. The lowermost portion 38 of this bore terminates at 40 which serves the purpose of a valve seat, as hereinafter described. The intermediate portion 42, directly above portion 38, is preferably somewhat smaller in diameter. The upper portion 44 has a diameter somewhat larger than portion 42. Portion 44 communicates by means of a plurality of radially extending passages 48 with an annular groove 50 formed in the outer surface of valve body 32. Groove 50 communicates with the passages in a plurality of nozzles 21 which are open to mixing chamber 14 of body 10.

A valve rod 54 is slidably positioned in the bore in valve body 32. Valve rod 54 forms an extension of the lower end of rod 24, and is preferably integral therewith. The lower end of valve rod 54 is provided with a generally conical sealing portion 56 which is adapted to engage valve seat 40 when valve rod 54 is in its upwardmost position for substantially closing the passage from bore 30 into bore 38. Immediately above sealing portion 56, valve rod 54 is tapered or shaped as shown at 58. Shaped section 58 cooperates with relatively restricted bore 42 to allow the fuel from bore 30 to nozzles 21, the flow of fuel being regulated by the vertical position of shaped metering portion 58 with respect to metering bore 42, as hereinafter described. The lower end of rod 54 is provided with a stud 60 carrying a spring 61 which abuts against the bottom of bore 30. Spring 61 resiliently urges rod 54 in an upward direction.

As can be seen by the above description, the position of valve rod 54 is controlled by the opposing forces comprising the resilient upward force of spring 61 balanced by the downward force caused by the impingement of the air on disc 22 as it flows from intake passage 12 into mixing chamber 14. An increase in the velocity of this air flow increases the downward force on disc 22 to move valve rod 54 further downwardly against spring 61. This will move shaped portion 58 partially out of restricted bore 42, increasing the cross-sectional area of the passage therebetween, thereby increasing the flow of fuel to nozzles 21.

Portion 58 of valve rod 54 has been described as being tapered or shaped. If this section constituted a straight taper, the amount of fuel supplied to the nozzles would vary in substantially straight line relationship to the downward displacement of disc 22 by the air flow. However, the displacement of disc 22 does not necessarily base a linear relationship with the quantity of the air flowing through mixing chamber 14 so that, in order to obtain a linear relationship between this flow of air and the amount of air supplied to the nozzles, portion 58 would have to have a contour corresponding to the curve of disc displacement versus air flow in order to provide a constant fuel-air ratio at all velocities of air flow. However, it is not necessarily desirable to have the fuel-air mixture constant for all air velocities, and any desired variation can be accomplished by suitable design of the shape of portion 58.

Internal combustion engines are generally started by cranking the same by hand or more generally by means of an electric starter. The rate at which an engine is cranked is relatively low, and is much smaller than the normal running or idling speed of the engine after it has started. This results in a very small air flow through mixing chamber 14 during cranking prior to starting. It is necessary to supply fuel to nozzles 21 immediately upon cranking the engine and thus, disc 22 must move downwardly enough to unseat member 56 for opening a passage for the fuel to nozzles 21 so that the engine will start. This is accomplished by the design of the shape of the lower portion of intake passage 12 and disc 22. As may be seen by an examination of FIG. 1, disc 22 substantially completely closes the passage from intake passage 12 into mixing chamber 14 when in its uppermost position. This substantially complete closure of the passage results in an appreciable downward force being exerted on disc 22 even at very low engine speeds, so that the disc will be moved an appreciable distance during the cranking of the engine. This substantial downward movement of disc 22 immediately opens the passage for flow of fuel from bore 30 to nozzles 21, and thereby assures an adequate supply of fuel at cranking speeds.

This quick opening action of the fuel metering valve may be increased, if desired. For example, disc 22 may be positioned in intake passage 12 when it is at or near its uppermost position. The lower end of intake passage 12 may also be tapered or otherwise shaped, so that downward movement of disc 22, partially out of the passage, enlarges the passage available for air flow at a predetermined rate. For example, a slight outward flaring of the lower end of intake passage 12 would slowly increase the passage available for the flow of air upon downward movement of the disc; and a larger angle of taper would have a more pronounced effect on the air passage for a given movement of the disc. Thus, it can be seen that, with the arrangement as described above, the position of disc 22 and the shape of the lower portion of intake passage 12 may be selected so as to result in a relatively large downward displacement of disc 22 by relatively small changes in the air flow into the intake manifold. This will not only accomplish an immediate and positive opening of valve 26 immediately upon cranking the engine for starting, but may be used to render valve 26 sensitive to very small variations in the air flow during low engine speeds. Such an arrangement, coupled

with the proper design of the shape of portion 58 results in an extremely accurate and responsive metering action during low engine speeds. However, when the engine reaches a certain predetermined speed, disc 22 will move away from the constricted intake passage 12, and be positioned within the relatively large mixing chamber 14. When this occurs, the action of the air on disc 22 is controlled by the velocity of the impingement of the air on the upper surface of the disc, and thus the position of the disc will be governed by the mass velocity of the air flowing through the mixing chamber 14.

From the above description, it is clear that the quantity of fuel supplied to chamber 14 is maintained at the desired rate proportional to the flow of air through the mixing chamber. The fuel to air ratio is thereby maintained at a constant predetermined value for any given fuel pressure existing in bore 30. However, as will be hereinafter described, the predetermined ratio of fuel to air may be varied by changing the fuel pressure in bore 30 by means of other controlling means, hereinafter described, to suit the needs of the particular conditions under which the engine is operating at any given time.

Fuel is supplied to bore 30 through a passage 62 from a pressure regulator shown generally at 64. Pressure regulator 64 is preferably connected to the output line of a fuel pump (not shown) of standard and known construction which delivers fuel at a substantially constant pressure.

Pressure regulator 64 includes a lower casing 66, an upper casing 68 and a cover 70. Lower casing 66 is provided with a vertically extending cylindrical bore 72 containing a cylindrical strainer 74. The lower end of bore 72 is sealed by means of a plug 76 which may be removed for access to strainer 74 for cleaning or replacement. Fuel is fed to bore 72 through a transversely extending threaded opening 78 which is adapted to receive a fuel line leading from the fuel pump.

Casings 66 and 68 cooperate to form a cavity which is divided into a lower chamber 80 and an upper chamber 81 by a diaphragm 82 which is clamped between lower casing 66 and upper casing 68. Chamber 80 communicates with bore 72 through a passage which is partially closed by a valve seat 84. A generally conical valve member 86 is located in bore 72 and extends upwardly through the passage in valve seat 84, and is attached to diaphragm 82.

A second cavity is formed by upper casing 68 and cover 70. This cavity is also divided into two chambers 90 and 91 by means of a diaphragm 92. Chamber 90 communicates with chamber 81, while chamber 91 communicates with the atmosphere through a vent 94. A regulating screw 96 is threadably mounted in cover 70, and abuts diaphragm 92 to limit its upward movement. Regulating screw 96 is preferably provided with a compression spring 97 to frictionally lock it in adjusted position.

A coil spring 98 mounted in chamber 90 has its lower end bearing against a seat 99 formed in upper casing 68 and its upper end bearing on the lower surface of diaphragm 92. Spring 98 is of sufficient power to cause diaphragm 92 to bear against adjustment screw 96 under all conditions, so that the position of the diaphragm is controlled only by the position of screw 96.

A second coil spring 100, of smaller diameter than spring 98, is mounted concentrically therewith. The upper end of spring 100 bears against diaphragm 92, and the lower end thereof bears on the upper surface of diaphragm 82, resiliently urging the same downwardly. The magnitude of the downward force applied to diaphragm 82 by spring 100 depends on the position of diaphragm 92, which may be adjusted by manipulation of screw 96.

Chamber 81 is connected to mixing chamber 14 by passages 102 and 104. This causes the upper surface of diaphragm 82 to be subjected to the pressure conditions existing in mixing chamber 14.

When the engine is operating normally, fuel is sup-

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plied under pressure by the fuel pump (not shown) to opening 73 whence it passes through strainer 74 into bore 72. The fuel then passes up through the annular space between valve 86 and valve seat 84 into chamber 80 and thence through passage 62 to bore 30.

The position of conical valve 86 with respect to valve seat 84 is controlled by the position of diaphragm 82, which, in turn, is controlled by the balance of upward and downward forces acting thereon. Upward force is exerted by the pressure of the fuel on the lower surface of diaphragm 82; downward force is exerted by spring 100 and the pressure effective on the upper surface of diaphragm 82, which corresponds to the pressure in mixing chamber 14 as explained above.

Should the pressure of the fuel delivered by the fuel pump increase, while all the other forces mentioned above remain constant, the increased pressure in chamber 80 will move diaphragm 82 upwardly. This moves conical valve 86 into closer relationship with valve seat 84 and narrows the passage for the flow of fuel into chamber 80, thereby causing the pressure of the fuel in chamber 80 to return to its original value. Pressure regulator 64 thereby automatically compensates for fluctuations in the pressure of the fuel supplied by the fuel pump, in order to maintain the fuel pressure in chamber 80 at a substantially constant predetermined value in order to supply fuel to metering valve 26 at constant pressure.

Should the engine be accelerating or running under heavy load, it is desirable that the amount of fuel supplied to mixing chamber 14 be increased in order to increase the richness of the fuel-air mixture. Acceleration or heavy loading of the engine will cause the pressure in mixing chamber 14 to rise (or the vacuum to fall) as is well known in the engine art. This increase in pressure in chamber 14 will be immediately communicated to chambers 81 and 90 through passages 102 and 104. This increase in pressure will increase the downward force on diaphragm 82 thereby moving conical valve 86 away from valve seat 84 which will increase the passage available for the flow of fuel to chamber 80. This results in an increase in the pressure of the fuel supplied to metering valve 26.

The downward force on diaphragm 82 caused by the pressure in chamber 81, as described above, is augmented by the downward force exerted by spring 100. Thus, the actual position of diaphragm 82 under any given conditions of manifold pressure will be controlled by the force exerted by spring 100. Since this force may be varied by the adjustment of screw 96, as described above, the richness of the mixture supplied to the engine may be controlled by the adjustment of screw 96. Downward adjustment of screw 96 increases the pressure exerted by spring 100 on diaphragm 82 and causes valve 86 to assume a more open position under any given conditions of manifold pressure, and thereby increases the pressure of the fuel supplied to metering valve 26, increasing the richness of the mixture supplied to the engine throughout its entire range of operation. Thus, downward adjustment of screw 96 causes a general increase in engine performance, particularly in the ability to accelerated and operate under sustained heavy loads. Upward adjustment of screw 96 has a converse effect, resulting in a leaner mixture throughout entire range of engine operation which will increase the economy of operation of the engine, but will adversely affect its acceleration and load carrying abilities.

When the throttle of an engine is suddenly opened, immediate enrichment of the fuel-air mixture is required in order to cause the engine to accelerate rapidly and smoothly. It has been found that the enrichment of the mixture caused by the increase in fuel pressure caused by valve 86 is too slow to cause immediate acceleration when the throttle is suddenly opened. For this reason, means are provided for immediately furnishing a quantity

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of fuel to nozzles 21 when the throttle is thus suddenly opened.

This accelerating means comprises a pair of casings 106 and 108 forming a cavity which is divided into upper and lower chambers 110 and 112 by means of a flexible diaphragm 114. The upper chamber 110 communicates with mixing chamber 14 through a pair of passages 116 and 118. Lower chamber 112 communicates with fuel passage 62 through a branch passage 120. Diaphragm 114 is resiliently urged downwardly by means of a coil spring 122 which abuts the under side of casing 108.

Since the pressure of the fuel in passage 62 is normally maintained at a positive value by pressure regulator 64, and the pressure in mixing chamber 14 is generally below atmospheric pressure, diaphragm 114 is normally forced upward against the urging of spring 122 and lower chamber 112 is normally full of fuel. However, sudden opening of the throttle results in a very rapid increase in pressure in mixing chamber 14. This sudden increase in pressure is communicated to chamber 110 by means of passages 102, 116 and 118. This increase in pressure combined with resilient force of compressed spring 112 forces diaphragm 114 downward and forces the fuel contained in chamber 112 into passage 62, thereby providing a surge of fuel to nozzles 21 to enrich the air-fuel mixture as required for sudden acceleration. It is to be noted that unlike the usual accelerator pump, the acceleration herein disclosed is completely controlled by the pressure conditions existing in mixing chamber 14 and is completely independent of the throttle linkage. An extra quantity of fuel is provided only when engine conditions are such that an increase is warranted. This results in a considerable saving of fuel, since the fuel normally contained in chamber 112 is supplied to the engine only when there is a considerable drop in manifold pressure unaccompanied by a corresponding rise in fuel pressure. During normal slow acceleration, the increase in manifold pressure communicated to chamber 110 above diaphragm 114 is at least partially compensated for by the increase in fuel pressure caused by pressure regulator 64. This holds diaphragm 114 in its normal position, and prevents the ejection of the fuel in chamber 112. This prevents a waste of fuel which normally occurs in conventional throttle operated accelerator pumps wherein the fuel in the cylinder is ejected into the carburetor whenever the throttle linkage is moved to a further opened position, irrespective of whether this movement is rapid or slow.

The sudden increase in pressure caused by the fuel forced into passage 62 by diaphragm 114, as described above, may cause a corresponding pressure surge in chamber 80. This forces diaphragm 82 in an upward direction, closing valve 86. This is precisely opposite to the effect desired during acceleration, since diaphragm 82 must move downwardly opening valve 86 to enrich the mixture. This interruption in functioning of pressure regulator 64 is prevented by the insertion of a check valve 124 in passage 62 between passage 120 and chamber 80. As soon as the pressure in passage 62 rises above the pressure in chamber 80, this valve will close. During the interval when valve 124 is closed, the increase in pressure in mixing chamber 14 will cause downward movement in diaphragm 82, as described above, causing the pressure in chamber 80 to increase. When the pressure in chamber 80 becomes equal to or greater than the pressure in passage 62, check valve 124 will open, and the normal flow of fuel will resume.

When an internal combustion engine is cold, it requires a richer mixture than when it is running at normal operating temperatures. Further, when an engine is running cold, it has less power than when it is running at normal operating temperatures and thus the throttle must be maintained further opened in order for the engine to idle without stalling. Means have, therefore, been provided for enriching the fuel and air mixture when the engine is cold and, at the same time, for pre-

venting the throttle from being fully closed during this period. These means comprise a flat, generally circular casing 126 closely associated with body portion 10, and having a chamber 128 therein. Chamber 128 is provided with a fitting 130 adapted for connection to a tube 131 which is connected to a casing 133 surrounding the exhaust pipe 135 of the engine. Casing 133 is provided with openings 137 so that air may be drawn into the chamber formed by casing 133 where it is heated by the exhaust pipe, and this heated air is supplied through tube 131 into chamber 128. A small air bleed hole 132 leads from chamber 128 into mixing chamber 14. Thus, when the engine is running, the vacuum in mixing chamber 14 draws air through the above mentioned tube and into chamber 128 through fitting 130 and thence through hole 132 into mixing chamber 14. The temperature of the air thus drawn through chamber 128 from the vicinity of the exhaust pipe of the engine will correspond to the temperature of the pipe, which in turn will roughly correspond to the temperature of the engine itself. Thus, when the cold engine is first started, the air drawn through chamber 128 and into mixing chamber 14 through hole 132 is cold and chamber 128 soon becomes filled with this cold air. However, as the engine begins to warm up, the temperature of the air drawn from the vicinity of the exhaust pipe begins to rise and thus the air in chamber 128 begins to rise a corresponding amount. Since the air drawn from the vicinity of the exhaust pipe is constantly passing through chamber 128, the temperature of the air in that chamber will closely correspond with the temperatures existing in that vicinity and thus with the temperature of the engine itself.

Chamber 128 is provided with a transversely extending substantially centrally located shaft 134 which is suitably mounted on bosses provided for the purpose. Shaft 134 carries a substantially U-shaped arm 136. A temperature responsive bi-metallic spring 138 is mounted in chamber 128 with one end rigidly fastened to the cover 139 (FIG. 3) of the chamber and the other end hooked in a slot 141 in arm 136. The rotational position of cover 139 may be adjusted to adjust the tension of spring 138.

Spring 138 is arranged so that a decrease in temperature causes it to coil itself applying a resilient clockwise force (as viewed in FIG. 1) to arm 136. Movement of arm 136 causes shaft 134 to rotate a corresponding amount.

Shaft 134 carries a small eccentric element 140 directly adjacent to arm 136. This eccentric engages a slot 142 in an arm 144 which is pivotally mounted on a suitable projection by means of a screw 146. The rotation of shaft 134 thus causes arm 144 to rock about screw 146.

Referring now to FIG. 2, the position of throttle 18 is controlled by means of throttle shaft 20 which projects through the side of the casing 10. Throttle shaft 20 carries an L-shaped arm 148 which is adapted for connection to a mechanical throttle linkage as is well known in the art. Arm 148 is provided with a pair of inwardly extending lugs 150 (FIG. 3) which contain threaded holes for the reception of an adjusting screw 152. Screw 152 is so positioned that when the throttle is moved to fully closed position, the end of the screw abuts the outer end of arm 144, as shown in FIG. 2. This contact of screw 152 with arm 144 limits the closing of the throttle.

When the engine is cold, the temperature of the air in chamber 128 is low, and the bi-metallic spring 148 rotates arm 136 in a clockwise direction. This causes shaft 134 to rotate in such a way that eccentric 140 rocks the lower end of arm 144 in a counter-clockwise direction, so that the upper end of the arm assumes the position shown in solid lines in FIG. 1. When arm 144 is in this position, the throttle cannot move to fully closed position, and so the engine will idle at a relatively high speed.

As the engine warms up, the temperature of the air passing through chamber 128 rises, causing spring 138 to

rotate in a counter-clockwise direction and the hook on the end of the spring moves away from the edge of slot 141. This releases the spring tension on arm 136 and allows arm 136 and eccentric 140 to rock arm 144 toward the position shown in dotted lines at 144a. This allows screw 152 and throttle arm 148 to move further downwardly so that the throttle may be moved nearer to closed position. The degree to which the throttle may be moved to closed position by the throttle linkage is thereby regulated by the temperature of the engine. When the cold engine is first started, the idling speed is relatively high, and this speed is progressively decreased as the exhaust pipe warms up, and thus soon after starting, the engine idles at normal speed. This action has the advantage of permitting the engine to idle at the minimum speed when it is warm in order to conserve fuel and at the same time providing for automatic fast idling when the engine is operating below normal temperatures so that danger of stalling is eliminated.

Arm 136, which is controlled by bi-metallic spring 138, as described above, is pivotally attached to a link 154 which is attached to a recessed tapered metering piston 160 which is slidably mounted in bore 158 which communicates with chamber 128. The top of bore 158 is closed by means of a cap screw 162 which is drilled and threaded for the reception of an adjusting screw 164 which extends downwardly into bore 158. Screw 164 is preferably provided with a spring 166 for frictionally holding it in adjusted position, and a second coil spring surrounds the lower portion thereof inside bore 158. The upper portion of this second spring 168 abuts against the lower surface of cap screw 162 and the lower surface thereof abuts against the bottom of the recess in piston 160 for resiliently urging the piston in a downward direction.

The upper portion of bore 158 above piston 160, communicates with mixing chamber 14 by means of a passage 170, so that the pressure existing in mixing chamber 14 is also effective to force piston 160 downwardly.

The lower portion of bore 158, adjacent the tapered metering section of piston 160, is provided with an annular groove 172 which communicates by means of a passageway 174 with an annular groove 176 on the outside of valve body 32. Groove 176 communicates with bore 42 by means of a plurality of radial passages 178.

During normal operation of the engine, the sub-atmospheric pressure or vacuum in mixing chamber 14 draws fuel from nozzles 21, and this suction results in sub-atmospheric pressure in bore 42. This sub-atmospheric pressure draws a current of air from chamber 128 past piston 160 to annular groove 172, and thence through passage 174, groove 176 and passages 178 into bore 44. This results in mixing the fuel in bore 44 with a small quantity of air so that the fuel as supplied to the nozzles is in the form of a froth rather than in the form of a solid stream. The presence of these bubbles in the fuel stream tends to facilitate the atomization of the fuel, but, more importantly, it also decreases the amount of fuel reaching the nozzles. Thus, the air bled into the fuel results in a leaner fuel-air mixture supplied to the engine.

The amount of air mixed with the fuel, as described above, is controlled by the position of piston 160 in bore 158. As piston 160 moves downwardly, the increasing diameter of the tapered section thereof restricts the passage from chamber 128 to annular groove 172. When the cylindrical portion of piston 160 covers groove 172, the air bleed is completely cut off. The position of piston 160 is controlled by the balance between the upward force exerted by the air under substantially atmospheric pressure in chamber 128, and the downward pressure caused by spring 168 and the sub-atmospheric pressure existing in bore 158 above piston 160. When the engine is cold, the downward forces are further aided by the resilient force exerted by bi-metallic spring 138 on arm 136.

When the engine is operating cold, the bi-metallic

spring 138 will draw piston 160 downwardly and the flow of air to annular groove 172 will be completely cut off. Thus, when the engine is operating cold, the air bleed is cut off and only pure fuel reaches nozzles 21. This results in an enrichment of the mixture when the engine is cold and fulfills the function of the choke on conventional carburetors. However, when the engine begins to warm up, the bi-metallic spring 138 begins to lose its ability to exert a force on piston 160 and allows piston 160 to move upwardly against spring 168. This uncovers groove 172 and allows air to bleed into the fuel. When the engine is at normal operating temperature, the position of piston 160 is controlled solely by the pressures existing on the opposite surfaces thereof and the downward force of spring 168. Under these conditions, the air bleed is such that the proper mixture is supplied to the engine.

It should be noted that the pressure existing in mixing chamber 14 is applied to the top of piston 160 through passage 170, as described above. Since the pressure in mixing chamber 14 increases during acceleration or heavy loading of the engine, the force acting to depress piston 160 is also increased. This causes piston 160 to move downwardly due to the force that spring 168 is always exerting on piston 160 to diminish or cut off the air bleed in order to enrich the fuel-air mixture supplied to the engine. This action augments the increase in fuel pressure caused by pressure regulating valve 64, in order to provide for the requisite enrichment for acceleration or heavy loading.

When the engine is idling at normal temperature, throttle 18 is almost completely closed, and thus, the pressure in mixing chamber 14 is very low. Further, the flow of air to the slowly running engine is relatively small under these conditions, so that disc 22 will be very near its upwardmost position, thereby minimizing the flow of fuel through valve 26 to nozzles 21. Under these conditions, the normal idling pressure in mixing chamber 14 would ordinarily draw piston 160 to its upwardmost position, greatly increasing the air bled to the fuel line through passageway 174. This causes the fuel to contain a very large proportion of air bubbles, so that the amount of fuel delivered to nozzles 21 is small. It has been found that under these conditions, when valve 26 is almost completely closed, and valve 160 is almost completely open, that the amount of fuel supplied to the engine is so small that the mixture may be excessively lean, which may cause stalling or backfiring. This condition is prevented by means of adjusting screw 164 which extends downwardly into bore 158 in a position to abut the bottom of the recess in piston 160. Screw 164 controls the maximum upward movement of piston 160 irrespective of the force exerted by the vacuum communicated to the top of the piston through passage 170. By proper adjustment of screw 164, composition of the mixture supplied to the engine during idling may be controlled so that the engine will idle smoothly. Screw 164 therefore constitutes an effective means for adjusting the mixture for idling when the engine is warm, but does not affect the composition of the mixture supplied when the engine is cold, since during these periods, piston 160 is held in a depressed position by means of a bi-metallic spring 138.

It is clear from the above description that this invention has attained all its stated objects. The position of the fuel metering valve 26 which controls the size of the passages leading to nozzles 21 is controlled by the action of the air flow on disc 22. Since the force acting on disc 22 to open valve 60 at normal engine speeds is caused by the impingement of the air on the valve, rather than by a differential pressure effect, this force is an accurate measure of the rate of flow of the air passing through the injector to the engine. The force exerted on disc 22 is independent of the absolute pressure existing in chamber 14 and thus responds to the mass of air flowing through the intake manifold independent of extraneous influences. The effect of any given movement of disc 22

on the quantity of fuel supplied to the nozzles is controlled by the shape of the valve rod and this shape may be designed to meter the amount of fuel to provide a fuel-air mixture corresponding closely to the theoretical ideal. Thus, the fuel injection system embodying this invention can be designed to provide an almost ideal fuel to air mixture for any engine throughout its entire normal operating range, resulting in extraordinarily high performance and economy.

The arrangement including the fuel metering valve 26 responsive to the air flow into the intake manifold also provides a positive automatic means for shutting off the flow of fuel entirely whenever the engine stops. As soon as the flow of air through mixing chamber 14 stops, spring 61 forces valve rod 54 upwardly, bringing sealing portion 56 into engagement with valve seat 40, effectively preventing further flow of fuel to nozzles 21. This not only effects a saving of fuel by prevention of bleeding of fuel to the nozzles after the engine has stopped, but constitutes a valuable safety feature built into the injector comprising this invention. In case of an accident or other mishap, as soon as the engine stops, the flow of air through mixing chamber 14 immediately comes to a halt. This effects an immediate stoppage of the fuel supply, effectively preventing fire from starting in the engine or intake manifold.

While fuel metering valve 26 is responsive solely to the mass of air passing to the intake manifold, compensation for the absolute pressure existing in mixing chamber 14 is supplied by pressure regulator 64 and air bleed piston 160. As described above, during acceleration or heavy loading of the engine, the pressure rises in mixing chamber 14 and at the same time the engine requires an enriched fuel-air mixture. This enrichment is accomplished by simultaneously cutting down the air bleed and increasing the fuel pressure. The degree of enrichment can be easily controlled by a simple adjustment of screw 96, as described above.

It is noted that in FIG. 1, pressure regulating screw 96 is shown as being covered by a cap 180 to prevent unauthorized tampering with this adjustment. However, it is also contemplated that, if desired, this adjustment screw may be exposed where it can easily be adjusted by the user of the vehicle so that he can regulate the engine to suit his own desires. For example, it is contemplated that a large head may be placed on adjusting screw 96, and an inscription placed thereon indicating that adjustment in one direction will increase economy while adjustment in the opposite direction will increase performance. This will allow even an unskilled user to regulate the operation of his engine to suit himself.

One other aspect of the action of pressure regulating valve 69 is significant here. As is well known, the engine of a vehicle is frequently used as a brake to slow the vehicle or to control its speed when descending steep hills, and the like. When this is done, the throttle will be closed, the flow of air is small, and the manifold vacuum will be very high. Ordinary carburetors, wherein the flow of fuel is controlled by the vacuum existing at the jets supply a large amount of fuel under these conditions, which, combined with the small air flow, results in an excessively rich mixture. This results in poor combustion which causes smoking, spark plug fouling, and dilution of the lubricating oil in the engine. More important, however, is the serious wastage involved in the burning of large quantities of fuel at a time when the engine is required to absorb rather than to supply power.

The pressure regulating valve 64 of the fuel injection system herein disclosed automatically corrects this undesirable condition. The abnormally high vacuum existing in mixing chamber 14 when the engine is decelerating or is acting as a brake will cause diaphragm 82 to move upwardly, completely closing valve 86, cutting off the flow of fuel to metering valve 26, and preventing the wastage

of any fuel when power is not required. Thus, valve 64 inherently acts as a "de-gasser," and thereby greatly increases engine economy.

This "de-gassing" action of valve 64 will normally cut off the fuel supply completely when the engine is acting as a brake. If it is desired to limit this action and to allow a small amount of fuel to flow to nozzles 21, this may be accomplished by supplying any convenient means for preventing valve 86 from completely cutting off the flow of fuel. Such means could, for example, consist of a small by-pass port between bore 72 and chamber 80, or a stud on the top of diaphragm 82 of sufficient length to contact the lower surface of diaphragm 92 to prevent complete closure of valve 86.

Adjustment of screw 152 will have no effect except on the position of the throttle during idling. Adjustment of idling mixture screw 164 will have no effect on the engine when running below normal temperatures since piston 160 is normally out of contact with screw 164 at all temperatures below that of normal operating range. Piston 160 is in contact with the screw 164 only at times when the engine is idling or rapidly decelerating. During these times, the adjustment of screw 164 serves to limit the degree of leanness that the mixture can attain and has no effect whatever on the operation of the engine under other conditions.

From the above description, it may be seen that each of the units comprising the fuel injection system embodying this invention serves to correct the fuel-air mixture under certain predetermined conditions in order to attain the proper mixture for the engine under all possible operating conditions. Moreover, since each of these components operates automatically, continuous correction of the fuel-air mixture is accomplished in order to obtain the optimum mixture under all operating conditions. Further, each of these components operates independently of all the other components and thus each may be designed to give the maximum theoretical efficiency irrespective of the other elements. For example, the shape of valve 54 may be designed to cooperate with the particular shape of the passages and mixing chambers to provide a quantity of fuel to the nozzles which is directly proportional to the amount of air flowing to the intake manifold. Thus, irrespective of the richness or leanness of the mixture desired, valve 26 may be designed to supply a fuel-air mixture of a predetermined composition over wide range of operating conditions.

The absolute value of this constant fuel-air ratio may be controlled by controlling the pressure of the fuel supplied to the metering valve. This is accomplished by the adjustment of pressure regulating valve 64 which can be preset to maintain the desired fuel pressure during normal operation of the engine. Abnormal conditions such as cold engine operation or sudden acceleration are independently compensated for by means of the other components described above. However, these compensations are accomplished without in any manner disturbing the exact calibration of the independent units which meter the fuel and control the mixture.

This invention has been described with reference to a schematic diagram shown in FIG. 1 which correctly shows the function of the various parts, but does not necessarily show their relative physical position. One arrangement of these parts is shown in FIGS. 2 and 3, which are side elevations and top plan views of one embodiment of this invention. However, this invention is not restricted to any particular arrangement of the parts, since other arrangements will readily occur to those skilled in the art. For example, it is contemplated that throttle 18 could be placed below mixing chamber 14 instead of above the chamber as shown in FIG. 1. This in no way would affect the operation of the other parts of the invention, since fuel metering valve 26 would still be controlled by the impingement of air on disc 22. Such an arrangement would, however, necessi-

tate the relocation of the outlets of passages 102 and 170 and hole 132 to a position downstream from the throttle so that these outlets would be subjected to intake manifold pressure.

It is also contemplated that the location of the nozzles could be varied. These nozzles have been shown in conventional location in mixing chamber 14; however, for certain applications it might be desirable to have a separate nozzle located immediately adjacent to the intake valve of each cylinder of the engine. In such a case, the nozzles 21 shown in the figures would be replaced by a plurality of suitable tubes which lead to the vicinity of the intake valves of each cylinder, and which terminate in a suitable atomizing nozzle. Under these conditions, it may be desirable to increase the pressure of the fuel supply in order to overcome the drop in pressure in the tubes leading to the nozzles. This may easily be done by making appropriate changes in pressure regulating valve 64 and, if necessary, by using a high pressure fuel pump.

While this injector has been shown as comprising one unit containing all the cooperating parts, it is clear that a different physical arrangement of the parts could easily be designed by those skilled in the art. For example, the pressure regulator could be placed at a position remote from the mixing chamber and the nozzles. Such rearrangement may be desirable where space is an important factor in design, and the fuel injector embodying this invention can be arranged with the various components positioned to fit into the desired space. This permits the design of a very compact unit which may be fitted into a small space in order to meet with styling or other requirements which may prevent the use of a relatively high unit. Moreover, the air may flow through mixing chamber 14 horizontally, or upwardly as well as downwardly, since the danger of fuel drippage is eliminated by the automatic shut off characteristics of the injector, as described above. From the above, it is clear that the injector embodying this invention is extremely flexible, and those skilled in the art could easily design a modification thereof which would fit into any available space in order to comply with space requirements imposed by engine or vehicle design.

Other changes in the physical arrangement and the specific details of this invention will occur to those who are skilled in the art, and it is not contemplated that this invention will be restricted to the particular configuration or combination of parts set forth in the example disclosed herein, but that this invention will be broadly interpreted as set forth in the appended claims.

I claim:

1. A fuel injector for an internal combustion engine having an intake conduit and a fuel line through which fuel is pumped under pressure, said injector comprising, in combination, fuel metering means in said fuel line responsive to the flow of air into said intake conduit for regulating the flow of fuel in relation to said air flow for controlling the fuel to air ratio, pressure regulating means in said fuel line, said pressure regulating means being responsive to intake conduit pressure for varying the pressure of the fuel supplied to said metering valve for varying the fuel to air ratio as required by engine load conditions, and air bleeding means open to the atmosphere and communicating with said fuel line, air metering means in said air bleeding means for controlling the quantity of air introduced into said fuel line, said air metering means being responsive to intake conduit pressure for varying the fuel to air ratio.

2. A fuel injector for an internal combustion engine having an intake conduit and a fuel line through which fuel is pumped under pressure, said injector comprising, in combination, a body portion having an air flow passage communicating with said intake conduit, movable means positioned in said passage and adapted to be displaced by the flow of air therethrough, metering valve

means in said fuel line for controlling the flow of fuel, said metering valve means being operatively connected to said movable means, whereby the flow of fuel is metered to control the fuel to air ratio, pressure regulating means in said fuel line, said pressure regulating means being responsive to intake conduit pressure for increasing pressure of the fuel supplied to said metering valve when said engine is under heavy load, air bleeding means open to the atmosphere and communicating with said fuel line, metering means in said bleeding means for controlling the quantity of air introduced into said fuel line, said metering means being responsive to intake conduit pressure for regulating the fuel to air ratio.

3. A fuel injector as claimed in claim 2 wherein said movable means comprises a disc mounted upon an extension of the operative part of said metering valve.

4. A fuel injector as claimed in claim 2 wherein said movable means is located to substantially obstruct said air flow passage when said metering valve is in closed position, whereby said movable means will be positively displaced by the flow of a small amount of air through said passage.

5. A fuel injector for an internal combustion engine having an intake conduit and an exhaust pipe, a throttle, and a fuel line, said injector comprising, in combination, fuel metering means in said fuel line responsive to the flow of air into said intake conduit for regulating the flow of fuel in relation to said air flow for controlling the fuel to air ratio value, pressure control means in said fuel line, said pressure control means being responsive to intake conduit pressure for regulating the pressure of the fuel supplied to said metering valve, and a temperature responsive means including a part adapted to engage said throttle for preventing the same from moving to fully closed position when said engine is cold.

6. A fuel injector as claimed in claim 5 wherein said temperature responsive element is actuated by the temperature of air drawn from the vicinity of said exhaust pipe.

7. A fuel injector for an internal combustion engine having an intake conduit and an exhaust pipe, said injector comprising, in combination, fuel metering means in said fuel line responsive to the flow of air into said intake conduit for regulating the flow of fuel in relation to said air flow, pressure control means responsive to intake conduit pressure for regulating the pressure of the fuel supplied to said metering valve, and means communicating with said fuel line having a reservoir for holding a quantity of fuel and means responsive to intake conduit pressure for forcing said fuel into said fuel line when said pressure increases for momentarily enriching said fuel and air mixture when said intake conduit pressure suddenly rises when said engine is accelerated.

8. A fuel injector for an internal combustion engine having an intake conduit and a fuel line through which fuel is pumped under pressure, said injector comprising, in combination, fuel metering means in said fuel line responsive to the flow of air into said intake conduit for regulating the flow of fuel in relation to said air flow for maintaining the fuel to air ratio at a predetermined value, pressure regulating means comprising a pressure regulating valve in said fuel line, pressure responsive element operatively connected to said pressure regulating valve, one side of said pressure responsive element being subjected to the pressure of fluid on the discharge side of the pressure regulating valve, the other side of said pressure responsive element being subjected to the pressure in said intake conduit, whereby said pressure regulating valve is adapted to regulate the pressure of the fuel delivered to said metering means in relation to the pressure in said intake conduit, air bleeding means communicating with the atmosphere and communicating with said fuel line, said air metering means being responsive to intake conduit pressure to decrease the flow of air when said intake conduit pressure increases, whereby

said pressure regulating means and air metering means cooperate to increase the fuel to air ratio when said engine is accelerating or under higher than normal load.

9. A fuel injector as claimed in claim 7 including means responsive to engine temperature for closing said air bleeding means when said engine is cold for enriching the fuel mixture.

10. A fuel injector for an internal combustion engine having an intake conduit and a fuel line through which fuel is pumped under pressure, said injector comprising, in combination, fuel metering means in said fuel line responsive to the flow of air into said intake conduit for regulating the flow of fuel in relation to said air flow for regulating the fuel to air ratio, pressure regulating means comprising a pressure regulating valve in said fuel line, a movable diaphragm operatively connected to said pressure regulating valve, one side of said diaphragm being subjected to the pressure of the fuel on the discharge side of said pressure regulating valve, the other side of said diaphragm being subjected to the pressure in said intake conduit, a spring for urging said pressure regulating valve toward open position, externally operable means for adjusting the force exerted by said spring, and sealing means interposed between said externally operable means and said spring for preventing the leakage of air into said pressure controlling means, air bleeding means open to the atmosphere and communicating with said fuel line, air metering means in said air bleeding means for controlling the quantity of air introduced into said fuel line, said air metering means being responsive to intake conduit pressure to decrease the flow of air when said intake conduit pressure increases, whereby said pressure regulating means and said air metering means cooperate to increase the fuel to air ratio when said engine is accelerating or under higher than normal load.

11. A fuel injector as claimed in claim 7 wherein said sealing means comprises a second flexible diaphragm.

12. A fuel injector for an internal combustion engine having an intake conduit and an exhaust pipe and a fuel line through which fuel is pumped at a substantially constant pressure, said injector comprising, in combination, fuel metering means in said fuel line responsive to the flow of air to said intake conduit for regulating the flow of fuel in relation to said air flow for regulating the fuel to air ratio in a predetermined manner, pressure regulating means in said fuel line, said pressure regulating means being responsive to intake conduit pressure for varying the pressure of the fuel supplied to said fuel metering means for adjusting the fuel to air ratio in response to engine load conditions, air bleeding means open to the atmosphere and communicating with said fuel line, air metering means in said air bleeding means for controlling the quantity of air introduced into said fuel line, said air metering means being responsive to intake conduit pressure to decrease the flow of air when said intake conduit pressure increases for increasing the fuel to air ratio when said engine is accelerating or under higher than normal load, a temperature responsive element operatively connected to said air metering means, means for drawing heated air from the vicinity of said exhaust pipe over said temperature responsive means, whereby the quantity of air bled to said fuel line is minimized when said engine is cold and is increased substantially proportionately to the increase in engine temperature.

13. A fuel injector as claimed in claim 12 including means operatively connected to said temperature responsive means and to said throttle for holding said throttle in partially open position when said engine is cold.

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