April 9, 1957 A. G. H. VANDERPOEL 2,788,082

FUEL INJECTION SYSTEM

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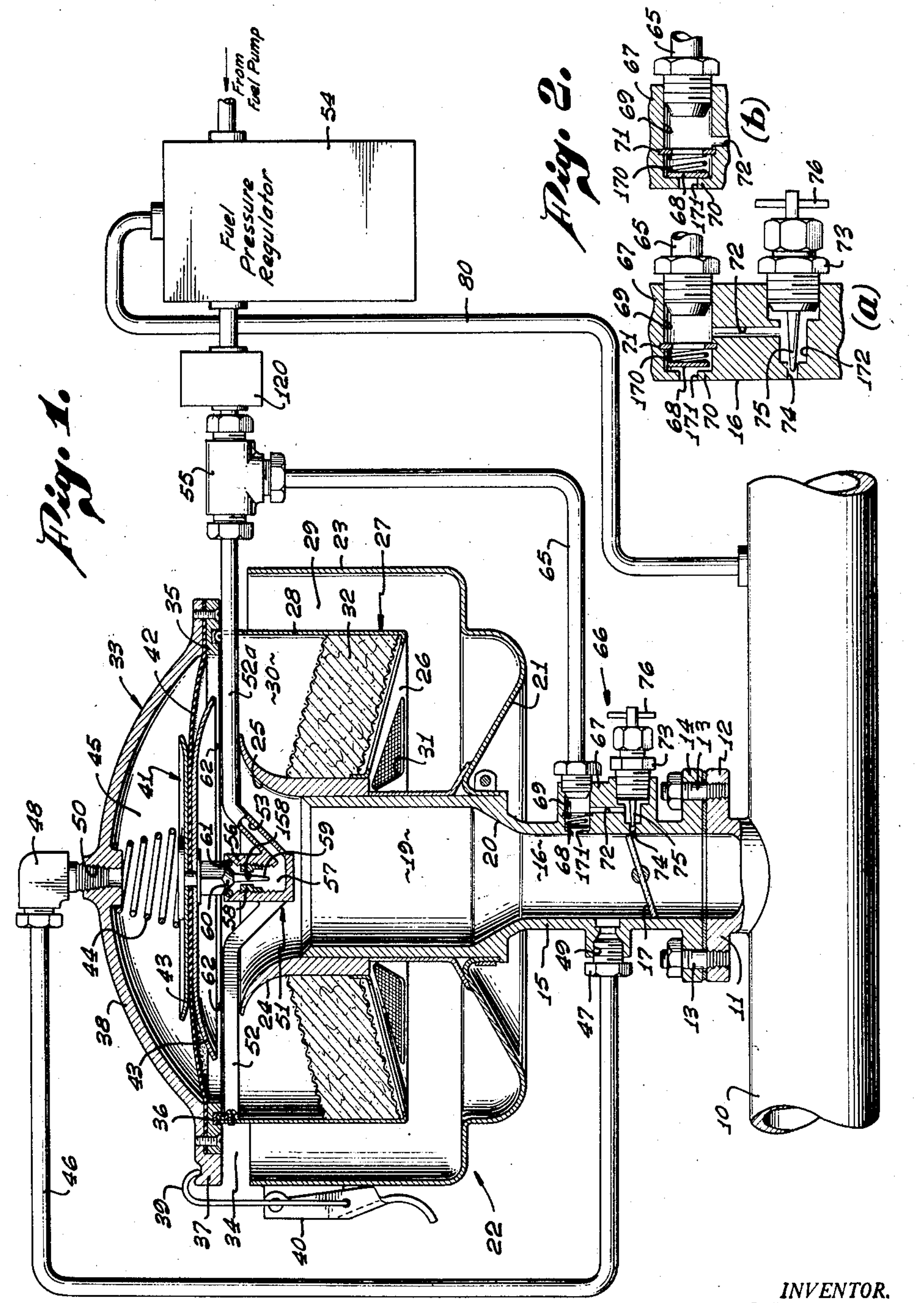

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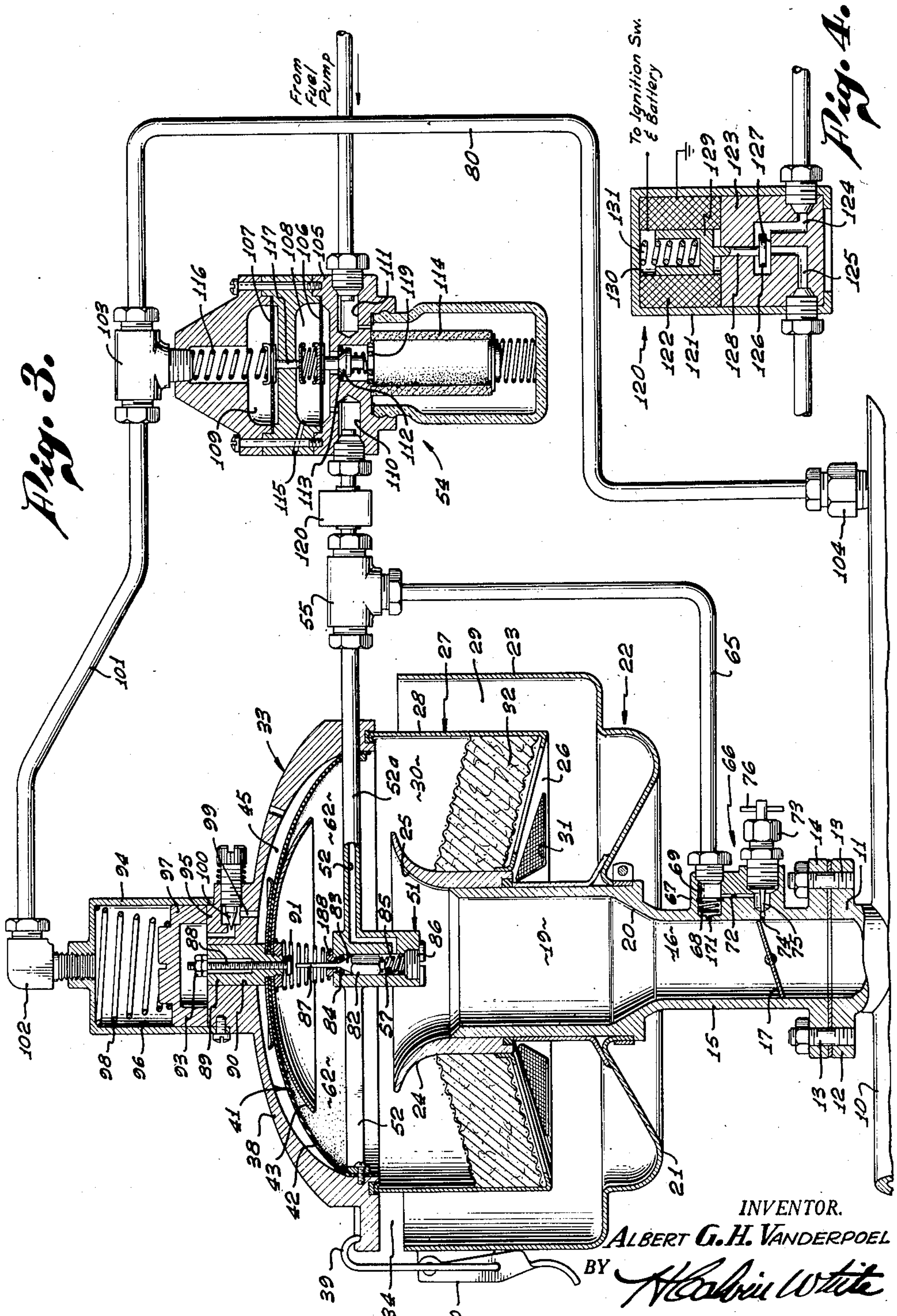

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FUEL INJECTION SYSTEM

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This invention relates to air-fuel supply systems for internal combustion engines, and more particularly has to do with apparatus external to such engines for combining cleaned air with injected fuel in such a way as to obtain improved mixing of fuel and air, having the effect of improving the distribution of fuel and air to the engine cylinders.

An appreciation of the objects and advantages of the novel air-fuel supply system to be described will be more easily gained after certain of the limitations of known systems have been reviewed. As has been realized in the past, ordinary suction-type carburetor systems in which fuel droplets are entrained in air flowing to an engine are subject to disadvantages having to do with poor fuel vaporization and mixture distribution, resulting in unequal distribution of the air-fuel mixture to the engine and consequent starving of the leanest cylinders. More importantly, the problems of mixture distribution have had to be considered and dealt with in that phase of carburetion having to do with the formation of desired maximum economy air-fuel mixtures at intermediate loads between idling and wide-open throttle engine operating conditions.

In order to overcome air-fuel distribution problems, various expedients that have been proposed and adopted have included the provision of "hot spots" on the manifold to help vaporize the fuel, richening the overall mixture to obtain the proper air-fuel ratio at the leanest cylinders, and the use of small manifold and carburetor throats to increase air velocities so as to aid atomization of liquid fuel in the air. While these and other expedients have been partially successful in obtaining better mixture distribution, they do not, for various reasons, give fully satisfactory results. For example, gains in fuel atomization sought through the use of small carburetor throats such as venturis are achieved only at the expense of air-flow restriction in the carburetor, with consequent decreased horsepower output of the engine.

Another approach to the problem has led to the development of devices for injecting fuel directly into engine combustion chambers; however, certain critical requirements necessarily imposed upon such injectors to a large extent off-set the advantages accruing from the elimination of mixture distribution problems resulting from their use. For example, such injectors must be made to withstand fluid pressures which increase rapidly with engine speeds, varying in proportion to the square thereof. Furthermore, combustion chamber fuel injectors are normally extremely complicated devices and are therefore subject to frequent mal-functioning.

The present invention has been predicated on the concept of providing thorough mixing of fuel with clean air prior to entrance of the mixture into the engine combustion chamber, so as to realize desirable air-fuel distribution to the various cylinders, with consequent increased smoothness in engine operation, more rapid throttle response, and increased fuel economy. In accordance with the invention, improved means are provided for thorough-

ly mixing pressurized fuel with clean air flowing to the engine in the proper air-fuel ratio over the normal range of engine operating conditions. More particularly, it is contemplated to effect continuous injection of liquid fuel into a stream of cleaned air passing through a turbulent air-fuel mixing zone, and subsequently to conduct the resultant mixture through a mixing passage leading to the engine manifold, so that the air-fuel mixture will be in condition favoring equal distribution thereof to the engine cylinders. Provision is also made for injecting pressurized fuel at a rate which varies in accordance with changes in the air-flow rate, so as to maintain desirable air-fuel ratios for maximum economy. Since thorough air-fuel mixing is achieved by injection technique, the air-flow passages may be widened or opened-up to minimize air-flow restrictions, resulting in greater air-fuel intake and increased horsepower development by the engine.

In carrying out these purposes, a chamber is provided external to the mixing passage, and an air cleaner is positioned in the chamber preferably at the side of the mixing passage walls, so that the air must reverse its flow direction after passing through the cleaner in order to enter the passage. A fuel-air mixing zone is advantageously located in the chamber between the cleaner and the inlet to the mixing passage wherein the air is caused to reverse its flow direction with resultant turbulence. Fuel is injected upstream into the mixing zone so as to take maximum advantage of air turbulence existent therein, aiding atomization and mixing of the fuel with air.

Desirable air-fuel ratios are maintained by means of a pressure sensitive movable diaphragm located in the mixing zone and forming a wall toward which air flows prior to reversing its direction. The diaphragm moves in accordance with pressure changes to vary the cross-sectional area of the zone through which air must flow, to aid air-fuel mixing at higher engine speeds, and also operates upon the injector valve to increase or decrease the quantities of pressurized fuel being injected into the mixing zone, for the purpose of maintaining desired air-fuel ratios. The geometry of the mixing zone, diaphragm, and injector is preferably such as to cause fuel to be injected toward the diaphragm structure and to be deflected off the surface thereof to enhance fuel-air mixing.

In keeping with the provision of a complete air-fuel supply system operative to deliver desired mixtures over the complete range of engine operating conditions, a throttle is provided in the mixing passage to regulate the speed of the engine, and since operation of the fuel injection apparatus is preferably restricted to non-idling engine operation, idle jet structure is provided at the outlet side of the throttle to deliver fuel to the mixing passage during engine idling.

Fuel is delivered to both the idle jet and the fuel injector nozzle from a pressure regulator, the delivery pressure of which may be modified in accordance with desired engine power development. In particular, a pressure regulator valve is provided in a fuel flow passage, and the valve opening is caused to be increased not only in response to decreased delivered fuel pressure, corresponding to increased opening of the injection valve, but also in response to increased absolute pressure of the air-fuel mixture flowing from the throttle to the engine. This arrangement tends to provide higher fuel pressures at the fuel injection nozzle to maintain efficient injection, in spite of increased nozzle opening, at time when greater engine power is sought to be developed. In addition, this arrangement furnishes quicker throttle response, since the control is directly sensitive to increased air-fuel mixture pressures between the throttle and the engine, corresponding to increased throttle opening.

Included in this invention is a means for obtaining quick opening of the fuel injector valve in order to effect the rapid formation of a rich air-fuel mixture for fast engine acceleration. To this end there is provided a piston slidable in a chamber communicating with the engine manifold and operative to displace the diaphragm assembly. During normal engine operation the piston is held in a first position against the force of a spring by suction pressure of the air-fuel mixture, which is communicable to the piston from a point between the throttle and the engine. However, when the throttle is opened, the mixture pressure rises and allows the spring to quickly urge the piston in a diaphragm displacing direction to effect rapid opening of the injector valve.

All the various features and objects of the invention, as well as the details of an illustrative embodiment, will appear more fully understood from the following description of the accompanying drawings, in which:

Fig. 1 is an elevation taken in section through the preferred embodiment of the invention;

Fig. 2 is a two-part enlarged view of the idle jet assembly, showing two operative positions thereof;

Fig. 3 is an elevation taken in section through a modified form of the invention, including a sectional view of fuel pressure regulator; and

Fig. 4 is an enlarged view of a solenoid controlled fuel valve for the fuel supply system.

In Fig. 1 there is shown an air-fuel intake manifold **10** for an internal combustion engine, with a short ducted carburetor fitting **11** connected into the manifold. To the flange **12** of this fitting there is joined by means of bolts **13** a flange **14** of an upright barrel or tube **15**. The lower portion of this tube contains a passage **16** which is narrowed to the diameter of the duct in the standard carburetor fitting **11**, the upper portion of the tube containing an enlarged diameter passage **19**. The walls of the two straight passages **16** and **19** are conveniently merged by a sloped wall **20** extending therebetween and pivoted throttle valve **17** is conveniently located in passage **16**. As shown in the drawing, the upper portion of the tube **15** projects upwardly through the closed base **21** of a receptacle or shell **22** having a cylindrical skirt **23** spaced outwardly from the tube. The base **21** of the receptacle may be bulged downward to provide a recess in which foreign particles may be collected, as will be described.

The upper portion of the tube **15** carries an outwardly and upwardly curved mouthpiece **24** forming a rounded approach orifice **25** at the mouth or inlet of the tube. To this mouthpiece there is conveniently joined the base **26** of a second and smaller receptacle or shell **27** having a cylindrical skirt **28** positioned between the mouthpiece **24** and receptacle skirt **23**. A passage or chamber **29** formed between the two receptacles communicates with chamber **30** within receptacle **27** through perforations or openings **31** in the base **26** thereof. In order that air passing through chambers **29** and **30** may be cleaned prior to entering passage **19** within the tube, an air cleaner comprising a mass **32** of foraminous material may be placed in one of the the chambers **29** or **30**, as for example between skirt **28** and mouthpiece **24**. Oil may also or alternatively be contained within the lower portion of receptacle **22** to provide a type of oil bath air cleaner at the location where air reverses its flow direction to enter chamber **30**. Foreign particles separated from the air stream reversing direction at the bottom of chamber **29** are conveniently collected in the recessed base **21** of receptacle **22**.

Above the two receptacles **22** and **27**, there is positioned a transversely extending head assembly **33** held against the rim of skirt **28**, which projects upward beyond the rim of skirt **23**, to provide an annular air passage **34** communicating with chamber **29**. Included in the assembly is a ring **35** containing an annular gasket **36** engaging the rim of skirt **28** when the head assembly is held in position over receptacle **27**. Ring **35** is connected to the flanged portion **37** of a dome **38**, and the flange is gripped by the jaws **39** of over-center clamps **40** joined to receptacle **22**.

Connected across the upper portion of chamber **30** and spaced above the mouthpiece **24** and beneath dome **38** is a diaphragm assembly **41**, including a movable diaphragm **42**, the edge of which is clamped between ring **35** and flange **37**, and upper and lower dished members **43** carried on opposite sides of the diaphragm. The diaphragm assembly is urged toward receptacle **27** by a compression spring **44** positioned between the dome **38** and the assembly **41**, and also is retractable toward the dome by suction pressure existent within chamber **45**, between the dome and the diaphragm assembly. Suction pressure is communicated from passage **16** to chamber **45** through line **46** connected to appropriate fittings **47** and **48**, which are respectively threaded into opening **49** above throttle gate **17**, and into opening **50** in dome **38**.

Conveniently positioned between diaphragm assembly **41** and passage **19** is a fuel injector nozzle assembly **51** carried at the center of transverse support **52**, which is connected to opposite sides of skirt **28**. Arm **52***a* of the support contains a duct **53** for supplying fuel to the injector nozzle **51** from a T-fitting, which is in turn connected to a fuel pressure regulator **54** through a solenoid controlled valve **120**. Nozzle **51** comprises a barrel **56** containing a fuel chamber or well **57** opening upwardly toward the diaphragm assembly **41**. Threaded within chamber **57** is a jet part **58** containing an orifice **158** through which projects a tapered pin **59** extending downward from a valve **60**, which is carried by the diaphragm assembly. Spring **44** urges the diaphragm assembly downward, forcing the tapered seating surface of valve **60** toward an O-ring seat **61** positioned at the upper end of chamber **57**. When the diaphragm assembly **41** is retracted upward by suction pressure in chamber **45**, valve **60** moves away from O-ring seat **61**, allowing pressurized fuel to be injected upward through orifice **158**, past tapered valve **60** and radially outward into an air-fuel mixing zone **62** located beneath the diaphragm assembly and on both sides of the mouthpiece **24**, where air entrance velocities are somewhat reduced. The rate of fuel injection through orifice **158** is, of course, controlled by the size of the orifice opening as determined by the axial position of the tapered pin **59**. Since the size of orifice **158** must be accurately controlled, the orifice is never closed by pin **59**, and seating of valve **60** on O-ring **61** is depended upon to cut off fuel injection.

Pressurized fuel is also conducted through line **65** from T-fitting **55** to an idle jet assembly **66**, which is positioned in a thickened wall portion **67** of the tube **15** near throttle gate **17**, and is shown in an enlarged view in Fig. 2. The T-fitting may contain a suitable restriction through which pressurized fuel is delivered to idle jet assembly **66**, for purposes to be described. Included in the jet assembly is an air-bleed check valve **68** carried in bore **69** and urged toward end wall **70** thereof by spring **170**, the opposite end of which engages a snap ring **71** mounted in the bore. An aperture **171** in end wall **70** communicates pressure in passage **16** to the check valve **68**. Also included in the assembly is a fuel passage **72** in thickened portion **67** communicating between bore **69** and a second bore **172** which is closed at one end by a threaded fitting **73** and open at the opposite end to define a small idle fuel passage or jet **74**. The latter opens into passage **16** immediately below the lip of throttle gate **17** when the gate is in closed position. The size of idle passage **74** may be varied by a tapered pin **75** projecting through fitting **73** and into passage **74**, and having an external handle **76** attached to the outer end thereof for adjusting purposes.

When the engine is started, pressurized fuel is forced thru a suitable restriction in T-fitting **55**, and to idle jet **74** via chamber **69** and passage **72**, check valve **68** remaining closed against end wall **70** under the action of light compression spring **170** and the fuel pressure. At this time, the throttle **17** is partly opened to admit sufficient air to mix with fuel discharging into passage **16** from idle jet **74**.

During idling conditions the throttle **17** is closed and the pressure in chamber **69** is reduced by the communication of high manifold vacuum thereto thru passages **172** and **72** from idle jet **74** downstream of the throttle valve. As a result, the check valve **68** moves rightwardly off wall **70** as seen in Fig. 2(*a*) against spring **170**, bleeding air at substantially atmospheric pressure from passage **16** through port **171** into chamber **69** where the air premixes with idle fuel and discharges at jet **74** downstream of the closed throttle.

As the throttle is gradually opened, the pressure in passage **16** upstream of the throttle decreases while the pressure in passage **16** downstream of the throttle increases along with the fuel pressure in line **65** and chamber **69**, to the point where check valve moves leftward against wall **70**, in Fig. 2(*b*), closing off the air bleed through port **171**. Thereafter, fuel is delivered to idle jet **74** without simultaneous air bleed thereto.

During acceleration and full load, low manifold vacuum conditions exist, so that no air is bled to the idle jet and fuel is injected at **74** under full fuel pump pressure.

During engine running conditions other than idling, throttle **17** is partly or fully opened so that reduced pressure is communicated to the mixing passage **16** immediately above the throttle and to chamber **45** above the diaphragm assembly **41** via line **46**. Under these circumstances, a condition of pressure unbalance is created on opposite sides of the diaphragm assembly, causing it to move upward, carrying valve **60** away from seat **61** and allowing pressurized fuel to escape therebetween and to be injected upward toward the diaphragm assembly and transversely outwardly, as controlled by the taper of the valve **60**. The injected fuel particles are directed oppositely to the in-flowing, reduced velocity air-stream and become distributed therein in mixing zone **62** on opposite sides of mouthpiece **24**. Any unmixed particles are suspended in the air filter **32** for subsequent entrainment by the inflowing clean air. Reduced pressure in passage **16** also induces air flow in greater quantities through chambers **29** and **30** in the receptacles toward orifice **25** at the mouth of mixing passage **19**. Since air flowing from chamber **30** into mixing passage **19** must reverse its direction in the region of mixing zone **62**, a condition of air turbulence is created in the latter zone favoring atomization and desirable distribution of the injected fuel in the air flowing through the mixing zone. In addition, injected fuel tends to impinge upon and to be deflected from the bottom surface of lower dished member **43**, with the result that fuel particles are caused to be well distributed in the turbulent air passing through the mixing zone. Conditions favoring further air-fuel mixing are set up in mixing passage **19** and passage **16**, through which the air-fuel mixture is subsequently conducted. By proper proportioning of the diaphragm assembly **41**, chamber **30** including mixing zone **62**, and the fuel injector nozzle components, desirable air-fuel ratios for maximum economy may be realized for engine operating conditions between idling and wide-open throttle operation. The achievement of better mixture distribution in the mixing zone **62** and in mixing passages **19** and **16** permits engine operation at more nearly correct air-fuel ratios instead of the usual somewhat richened mixtures, with gains in fuel economy resulting therefrom. In addition, the provision of air-fuel mixture passages without restrictions therein permits increased air-fuel intake, with resultant gains in horsepower output of the engine.

During engine idling conditions, pressurized fuel is conducted through line **65** to idle jet **74**. The correct air-fuel mixture for idling is, of course, easily obtained by adjusting the position of tapered pin **75**. At other than engine idling conditions, reduced pressures in passage **16** are communicated through opening **171** to the bleeder check valve, which is then forced against wall **70** by spring **170** to close the air opening **171**. During acceleration from idle conditions, the idle jet acts as an accelerating jet to quickly deliver increased quantities of fuel in response to opening of throttle valve **17** before the main fuel injector assembly **51** responds. This will occur when fuel pressure regulator **54** delivers increased fuel pressure in response to increased mixture pressure conditions downstream of throttle **17** before diaphragm assembly **41** responds to reduced pressure conditions upstream of the throttle.

Fuel is supplied to both the injection nozzle **51** and the idle jet assembly **66** from the fuel pressure regulator **54**, which will be described in connection with Fig. 3. As will be brought out, the action of the regulator is modified in accordance with pressure conditions in the manifold **10** communicated to the regulator by line **80**, so that delivered fuel pressure is appropriately raised or lowered to increase the operating efficiency of the fuel supply system. The solenoid controlled valve **120** between the regulator **54** and T-fitting **55** will be described in connection with Fig. 4.

Referring to Fig. 3 of the drawings, certain modifications in the head assembly **33**, diaphragm assembly **41** and injector nozzle **51** are shown in newly numbered detail, while those structural elements remaining the same as in Fig. 1 are given like numerals. The valve **82** in the bore **57** of the injector nozzle has an upwardly facing tapered seating surface **83**, the latter being urged against an O-ring seat **84** by a compression spring **85** inserted between the valve and a plug **86** threaded into the base of the nozzle. An elongated and tapered pin or pintle **87** projects upward from the valve through an aperture in jet part **188** threaded into the upper end of the nozzle and providing a small orifice to desirably shape and meter the injected fuel charge. The projecting end of pin **87** is engageable by the lower end of a threaded adjusting member **88** carried by plunger **89**, which is slidably mounted in a bore **90** in head assembly **33**. The lower end of the plunger is rigidly connected to the diaphragm assembly **41**, and a compression spring **91** is inserted between the upper end of the injector nozzle **51** and the diaphragm assembly. The diaphragm assembly is urged by the spring toward the dome **38** of the head assembly, but will also tend to be moved in the opposite direction by suction pressure communicated to the mixing zone **62** beneath the diaphragm, chamber **45** between the diaphragm assembly and dome **33** being open to the atmosphere through an appropriate vent therein. In accordance with this arrangement, when the throttle gate **17** is partly or fully opened, suction pressure communicated to the mixing zone **62**, causes downward movement of the threaded member **88** into engagement with the pin **87** and subsequent opening of the injector valve. Thus, operation of the modified fuel injection system is substantially the same as that described in connection with Fig. 1. Adjustments in the rate of fuel injection may be secured by loosening a locknut **93** threaded onto the upper end of member **88** so that the latter may be moved in plunger **89** relative to valve pin **87**. In this way, opening of the fuel injector valve as a result of movement of the diaphragm assembly may be changed to secure optimum operation of the injection system.

Quick opening of the injector valve is attained by the provision of additional mechanism located on top of the head assembly **33** as will now be described. The mechanism includes a tubular member **94** attached to a boss **95** formed on the top of the head assembly. The upper end of member **94** is closed to provide a chamber **96** therein which contains a plunger **97** and a spring **98**, urging plunger **97** toward the plunger **89** carried in the boss. That portion of the chamber **96** beneath plunger **97** also communicates with chamber **45** in the head assembly via passages **99** in the boss, which may be constricted as desired by a valve **100** threaded into the boss. The chamber portion above the plunger **97** communicates with the engine manifold **10** via lines **101** and **80**, and fittings **102**, **103** and **104**, as shown.

Under engine operating conditions corresponding to throttle openings other than wide-open, the reduced pressure of the air-fuel mixture in manifold **10** is communicated to chamber **96** and is sufficient to hold plunger **97** in a retracted position in the upper portion of the chamber so that spring **98** is compressed. Should rapid acceleration of the engine be desired, throttle gate **17** is opened wide, and the resultant increase in pressure of the air-fuel mixture in manifold **10** is communicated to chamber **96** so that the suction on plunger **97** is reduced. As a result, spring **98** forces plunger **97** toward the bottom of chamber **96**, displacing air underneath the plunger and thereby effecting downward displacement of diaphragm plunger **89** to quickly open the injector valve **82**, allowing a larger quantity of fuel to be injected into the mixing zone. Under these conditions a considerably richened mixture is formed in zone **62** and subsequently conducted to the engine for maximum power operation. Since air in chamber **96** between the two plungers also tends to escape to atmosphere via passages **99**, lesser or greater sensitivity of plunger **89** to movement of plunger **97** can be realized by adjustment of constricting valve **100**.

As mentioned earlier in this description, pressurized fuel is supplied to the injector nozzle and to the idle jet from a fuel pressure regulator **54**, which will now be described. In the regulator body **105** are positioned two diaphragms **106** and **107** extending across separated chambers **108** and **109**. The underside of diaphragm **106** communicates with fuel outlet **110** in the body and also with fuel inlet **111** when valve **112** carried by the diaphragm is displaced downward away from valve seat **113**. Valve **112** is urged toward seat **113** by a spring **119** therebeneath, and between the valve **112** and the inlet **111** may be included a fuel filter **114**, as shown in the drawing. The upper side of diaphragm **106** and the under side of diaphragm **107** communicates with the atmosphere through a vent **115** in the body **105**. The upper side of diaphragm **107** communicates with manifold **10** through T-fitting **103** and line **80**. A compression spring **116** urges diaphragm **107** toward diaphragm **106**, these two members being interconnected by means of a plunger **117** carried by diaphragm **107** bearing against a compression spring **118** inserted between the upper face of diaphragm **106** and the plunger.

When manifold pressures are considerably reduced below atmospheric pressure, as during idling and small throttle gate openings, suction pressures in the manifold are communicated to the upper side of diaphragm **107**, causing upward displacement thereof against the force of spring **116** with consequent relieving of the pressure on spring **118**. Under these conditions, the position of valve **112** is controlled by diaphragm **106** and spring **118** to regulate the pressure of fuel being delivered to the injector nozzle and idle jet.

Increased opening of the throttle gate **17**, as during acceleration conditions, effects an increase in manifold pressure, causing a reduction in the pressure differential across diaphragm **107** and thereby allowing spring **116** to displace diaphragm **107** downwardly to increase the pressure on spring **118**. As a result, diaphragm **106** is urged downward to open valve **112**, tending to increase the pressure of fuel being delivered to the injector nozzle.

Accordingly, it will be apparent that delivered fuel pressures will be increased at those times when greater power is demanded from the engine, corresponding to higher fuel injection rates. As a result, efficient injection spray patterns are maintained, in spite of larger nozzle openings, since delivered fuel pressure increases as the nozzle opening increases.

The solenoid controlled valve **120** through which fuel is supplied to the injector is shown in Fig. 4 to comprise a shell **121** containing a solenoid **122** and a valve body **123** at opposite ends thereof. Inside the body are fuel entrance and exit passages **124** and **125** communicating with one another when neoprene valve **126** is withdrawn from seat **127** in the body. The valve is carried by stem **128** of a plunger **129** which is positioned within a cylindrical aperture **130** in the solenoid. Actuation of the solenoid is conveniently controlled by an automobile ignition switch to effect retraction of the plunger and movement of valve **126** off seat **127** when the switch is closed, allowing pressurized fuel to pass through the valve opening when the engine is running. Upon opening of the switch the solenoid circuit is broken, following which the compression spring **131** bearing against the plunger causes closing of the valve and interruption of fuel flow. Accordingly, when the engine is not running, fuel cannot leak at the injector nozzle or at the idle jet since valve **126** is closed.

I claim:

1. Apparatus for supplying an air-fuel mixture to an internal combustion engine, comprising means forming an air-fuel mixing passage having an inlet and an outlet at opposite ends thereof, a throttle valve in said passage, an idle fuel jet communicating with said passage at the outlet side of said throttle valve, means forming a chamber extending across and about the inlet end of said first means and opening about said first means to the exterior for flowing air received throughout said chamber opening toward said inlet and at an angle to air flow in said passage, said chamber including a zone extending across said inlet and through which air flowing thereto is adapted to change its flow direction, a fuel injector nozzle opening upstream into said zone for injecting pressurized fuel upstream within said zone during non-idling engine operating conditions, and means for delivering pressurized fuel to said jet and to said fuel injecting means.

2. Apparatus for supplying an air-fuel mixture to an internal combustion engine, comprising tubular means forming an air-fuel mixing passage having an inlet and an outlet at opposite ends thereof, a throttle valve in said passage, an idle fuel jet communicating with said passage at the outlet side of said throttle valve, means forming a chamber extending across and annularly about the inlet end of said tubular means and opening annularly about said tubular means to the exterior for flowing air received throughout said chamber opening centrally toward said inlet and at an angle to air flow in said passage, said chamber including a zone extending across said inlet and through which air flowing thereto is adapted to change its flow direction, an annular air filter in said chamber, a fuel injector nozzle opening upstream into said zone for injecting pressurized fuel upstream toward said filter for mixing with filtered inflowing air during non-idling engine operating conditions whereby said filter may receive and suspend unmixed fuel for subsequent entrainment by said inflowing air, and means for delivering pressurized fuel to said jet and to said fuel injecting means.

3. Apparatus for supplying an air-fuel mixture to an internal combustion engine, comprising tubular means forming an air-fuel mixing passage having an inlet and an outlet at opposite ends thereof, a throttle valve in said passage, an idle fuel jet communicating with said passage at the outlet side of said throttle valve, means forming a chamber extending across and about the inlet end of said first means and opening about said first means to the exterior for flowing air received throughout said chamber opening toward said inlet and at an angle to air flow in said passage, said chamber forming means including a pressure sensitive movable diaphragm spaced opposite said inlet and forming a zone extending there-

across through which air flowing from said chamber to said inlet is adapted to change its flow direction with reduced velocity in relation to air velocity in said passage, an annular air filter in said chamber, a fuel injector including a nozzle opening into said zone toward the diaphragm and operable in response to diaphragm movement to variably inject pressurized fuel against the diaphrgam and upstream toward said filter for mixing with filtered inflowing air during non-idling engine operating conditions whereby said filter may receive and suspend unmixed fuel for subsequent entrainment by said inflowing air, and means for delivering pressurized fuel to said jet and to said fuel injector.

4. The invention as defined in claim 3 comprising a nozzle orifice and a movable element projecting through said orifice and controlled by said diaphragm for metering fuel flow through said nozzle in accordance with said pressure conditions.

5. The invention as defined in claim 4 comprising means forming a space at the side of said diaphragm opposite said zone and including a conduit connected into said space and into said passage at the inlet side of the throttle for communicating increased suction pressures at the inlet side of said throttle to said space for effecting displacement of said diaphragm and said element in a direction tending to increase the size of said orifice.

6. The invention as defined in claim 4 comprising a nozzle valve movable by said diaphragm to engage a nozzle seat for interrupting fuel flow through said orifice upon exposure of said diaphragm to atmospheric pressure conditions at the inlet side of said throttle.

7. The invention is defined in claim 4 comprising a conical nozzle opening directed toward said diaphragm to inject fuel in a conically diverging spray pattern upstream into the air flowing through said zone centrally toward said inlet.

8. The invention as defined in claim 6 including a spring urging said valve toward said seat.

9. The invention as defined in claim 4 comprising means responsive to reduce suction pressures at the outlet side of said throttle valve for displacing said diaphragm and said element in a direction tending to increase the size of said orifice.

10. The invention as defined in claim 9 comprising a housing containing a second chamber at the side of said diaphragm opposite said zone, a plunger in said second chamber operatively interconnected with said diaphragm, a spring urging said plunger in a direction tending to effect diaphragm and element displacement to increase the size of said orifice, and means for communicating to said plunger reduced pressures at the outlet side of said throttle to urge said plunger in a spring counteracting direction.

11. The invention as defined in claim 3 in which said last named means comprises a fuel pressure regulator having its discharge directly connected with said jet and fuel injector for receiving pressurized fuel from a fuel pump and delivering fuel to said jet and fuel injector at substantially regulated pressure in response to fuel pressure fluctuations directly communicated from said jet and fuel injector to the regulator.

12. The invention as defined in claim 11 in which said regulator includes a movable regulator valve controlling fuel flow through a valve opening and a pressure regulating diaphragm connected with said valve and exposed to fuel pressure at the outlet side of said regulator valve.

13. The invention as defined in claim 12 including another diaphragm movable in response to changes in air fuel mixture pressures at the outlet side of said throttle and operatively connected with said regulator valve for displacing it to further open said valve opening in response to increased mixture pressures at the outlet side of said throttle.

14. The invention as defined in claim 13 including another spring urging said regulator valve in a direction to close off fuel flow through said opening in response to communication to said other diaphragm of pressure conditions substantially below atmospheric pressure at the outlet side of said throttle when said throttle is closed.

15. Apparatus for supplying an air-fuel mixture to an internal combustion engine, comprising tubular means forming an air-fuel mixing passage having an inlet diverging in the upstream direction and an outlet at opposite ends thereof, a throttle valve in said passage, an idle jet communicating with said passage at the outlet side of said throttle valve for delivering fuel thereto during engine idling conditions, a shell forming an air-flow chamber extending across and annularly about the inlet end of said tubular means and opening annularly about said tubular means to the exterior for flowing air received throughout said chamber opening centrally toward said inlet and at an angle to air flow in said passage, said chamber including a zone extending across said inlet and through which air flowing thereto is adapted to change its flow direction with reduced velocity in relation to air velocity in said passage, an annular air filter in said shell, a movable diaphragm mounted opposite said inlet at one side of said zone for movement toward and away from said inlet in response to air-fuel mixture pressure changes in said zone, a fuel injector nozzle opening into said zone toward the diaphragm and operable in response to diaphragm movement to variably inject pressurized fuel against the diaphragm and upstream toward said filter for mixing with filtered inflowing air during non-idling engine operating conditions whereby said filter may receive and suspend unmixed fuel for subsequent entrainment by said inflowing air, said nozzle having an orifice and a movable element directly connected with said diaphragm and projecting through said orifice for metering fuel flow through said nozzle in response to said air-fuel mixture pressure changes, and means for delivering pressurized fuel to said idle jet and to said injector nozzle.

16. The invention as defined in claim 15 including a duct communicating with said passage at the inlet side of the throttle valve and said idle jet during engine idling conditions for conducting air to the pressurized fuel flowing to said jet during idling.

17. The invention as defined in claim 16 including a pressure sensitive valve in said duct adapted to close for preventing said air conduction in response to opening of said throttle valve.

18. The invention as defined in claim 15 in which said means comprises a fuel pressure regulator having its discharge directly connected with said nozzle and idle jet, and a solenoid actuated valve connected in series with said regulator for passing fuel to said nozzle and idle jet only during operation of said engine.

19. Air-fuel supply apparatus for an internal combustion engine, comprising a tube having an upwardly opening inlet and an outlet at opposite ends thereof, a throttle gate in said tube, an air cleaner shell removably mounted on and surrounding said tube in outward spaced relation thereto and containing foraminous material for flowing air to said inlet and filtering the flow through said material in a direction opposite to air flow in said tube, said shell having an upwardly opening end communicating with said inlet, a movable diaphragm extending transversely across and spaced from said open end of the shell and said tube inlet and forming therewith a zone for passing air flowing from said shell reversibly into said tube, a fuel injector nozzle opening directly into said zone toward the diaphragm to variably inject pressurized fuel against the diaphragm and upstream toward said material for mixing with filtered inflowing air whereby said material may receive unmixed fuel for subsequent entrainment by said inflowing air, and an element carried by said diaphragm and movable within said nozzle for controlling the rate of fuel injection through said

nozzle in accordance with movement of said diaphragm toward and away from said inlet in response to pressure changes in said zone.

20. The invention as defined in claim 19 in which said air cleaner shell has a downwardly opening entrance, and including an outer shell surrounding said air cleaner shell in outward spaced relation thereto and extending below said entrance for flowing air reversibly into said entrance.

21. The invention as defined in claim 20 in which said outer shell contains an oil bath below said entrance and over which air is adapted to flow reversibly into said entrance.

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