Jan. 19, 1960 H. GOLD ET AL 2,921,569

FUEL INJECTION SYSTEM

Filed Dec. 27, 1957 4 Sheets-Sheet 1

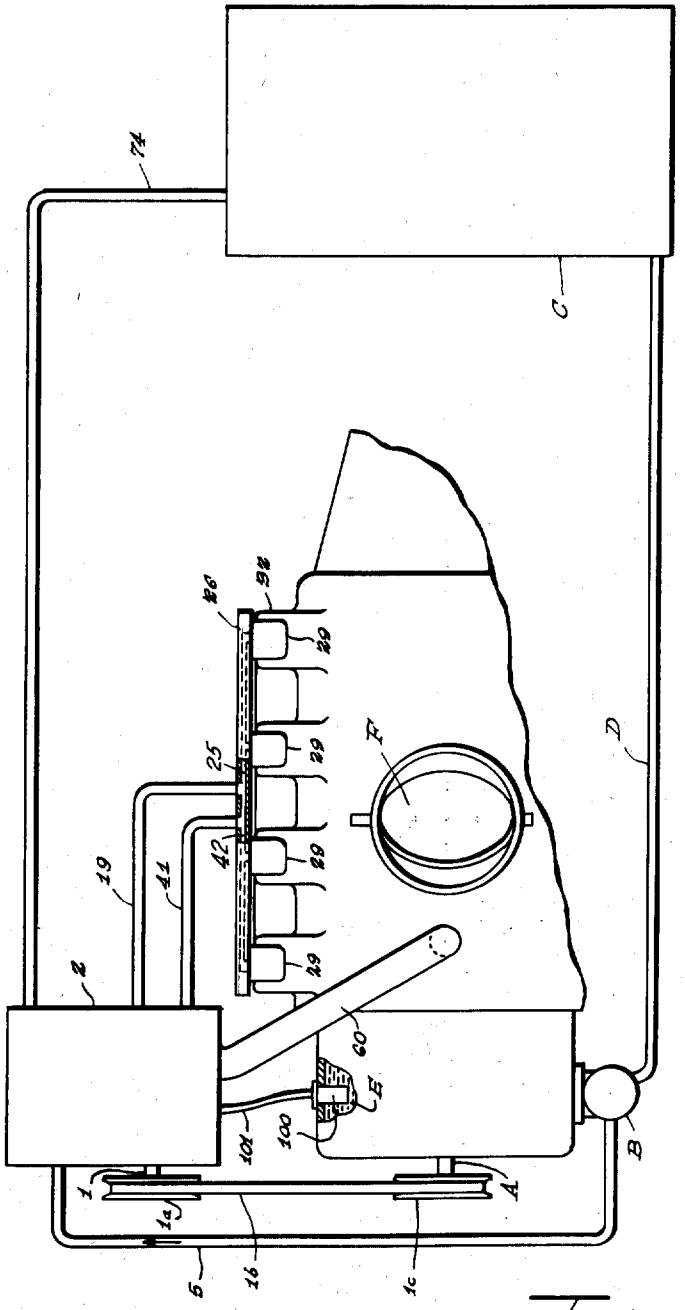


Fig. 1

Inventors
Harold Gold
David M. Straight

By Mill, Sherman, Meroni, Gross & Simpson Attys

Jan. 19, 1960 H. GOLD ET AL 2,921,569

FUEL INJECTION SYSTEM

Filed Dec. 27, 1957 4 Sheets-Sheet 2

Fig. 3

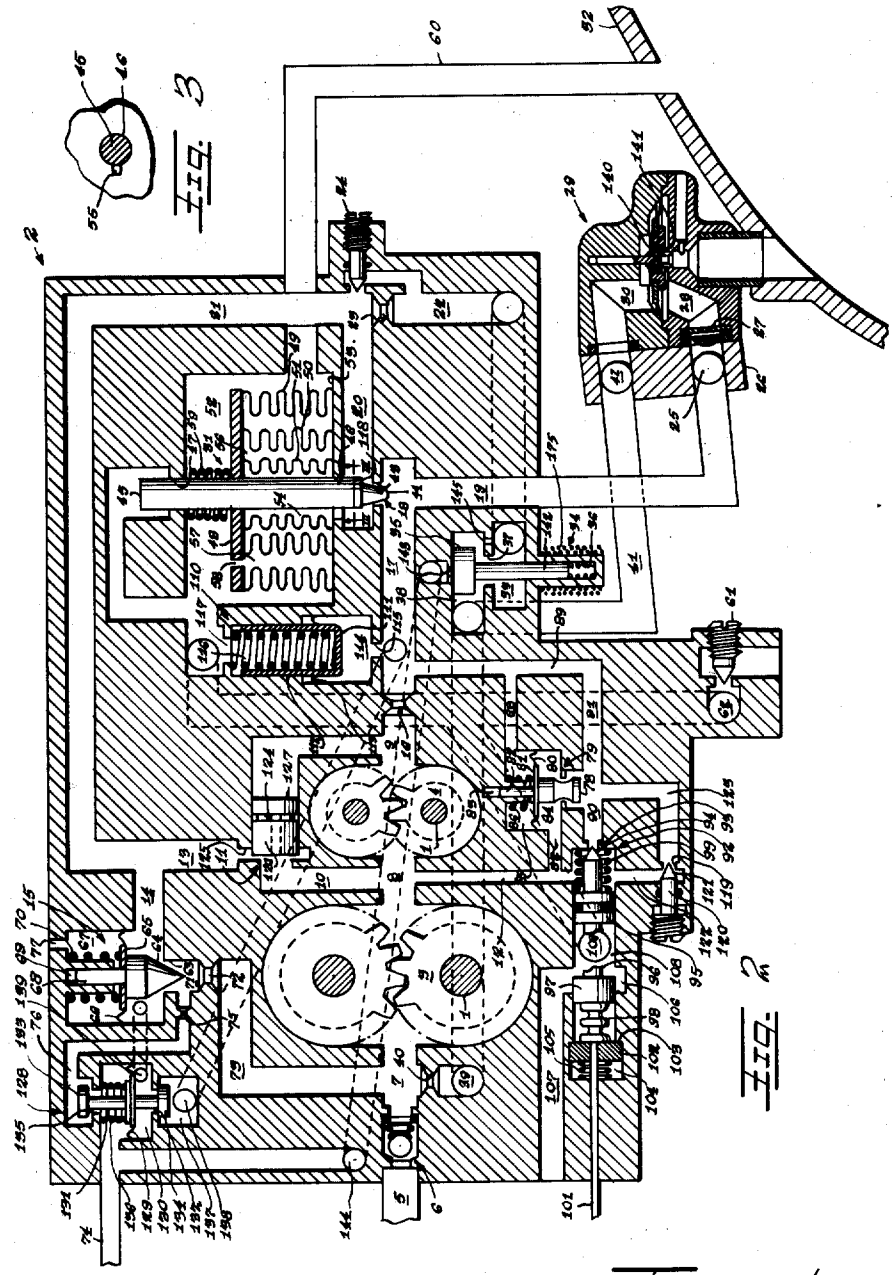


Fig. 4

Inventors
Harold Gold
David M. Straight
By Hill, Sherman, Meroni, Gross & Simpson Attys

Jan. 19, 1960 H. GOLD ET AL 2,921,569

FUEL INJECTION SYSTEM

Filed Dec. 27, 1957 4 Sheets-Sheet 3

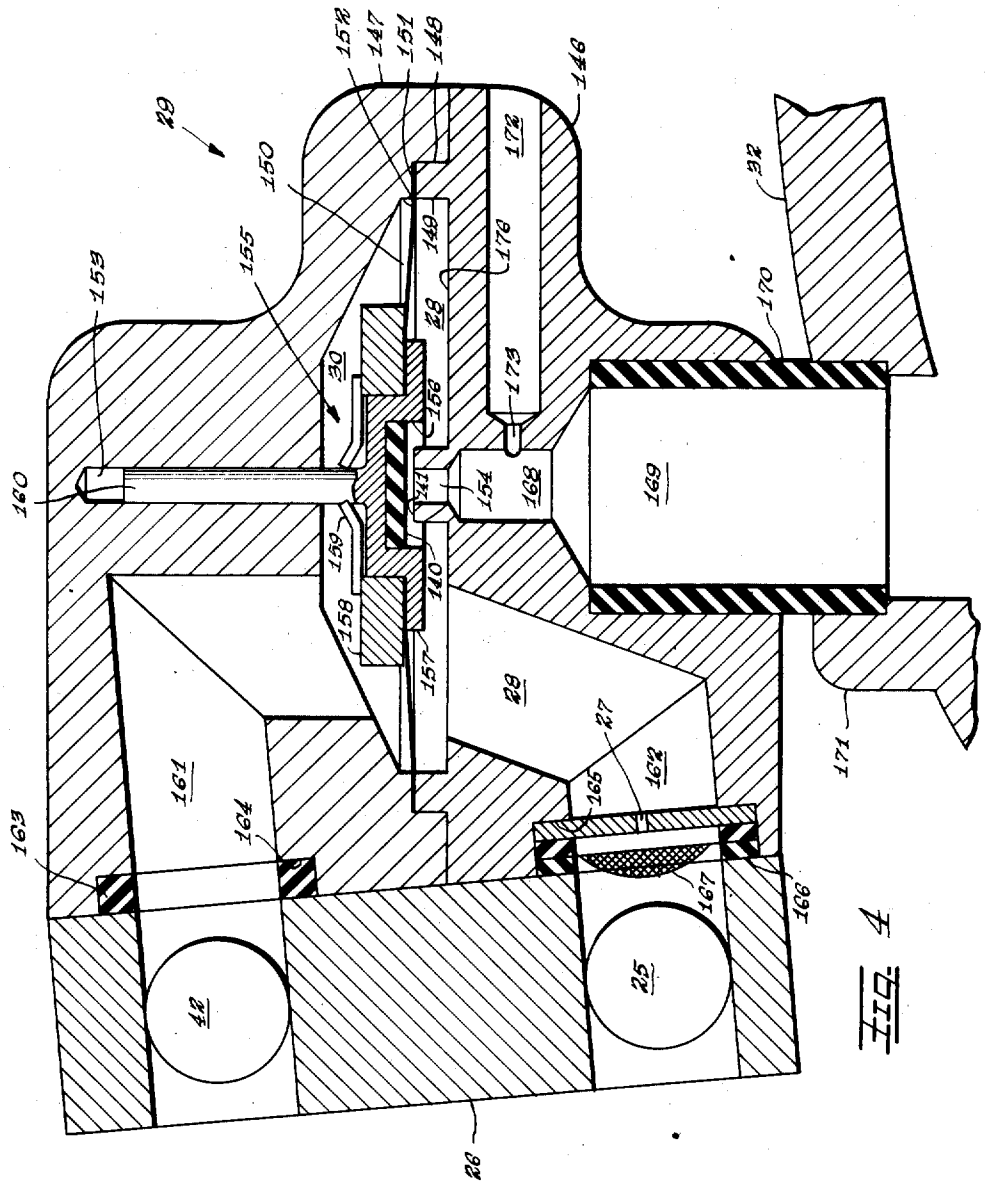


Fig. 4

Inventors
Harold Gold
David M. Straight

By Hill, Sherman, Meroni, Gross & Simpson Attys

Jan. 19, 1960 H. GOLD ET AL 2,921,569

FUEL INJECTION SYSTEM

Filed Dec. 27, 1957 4 Sheets-Sheet 4

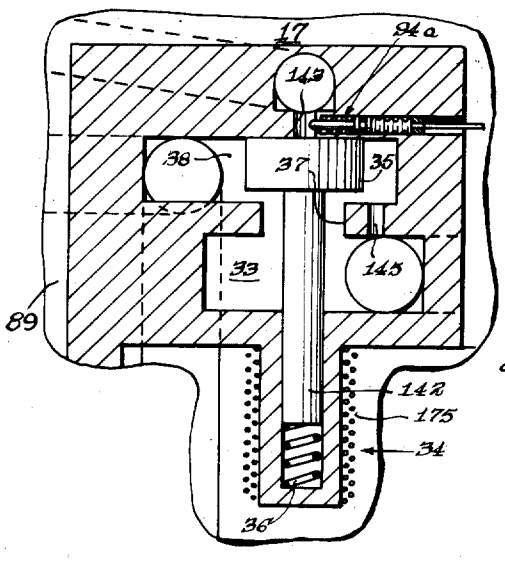


Fig. 5

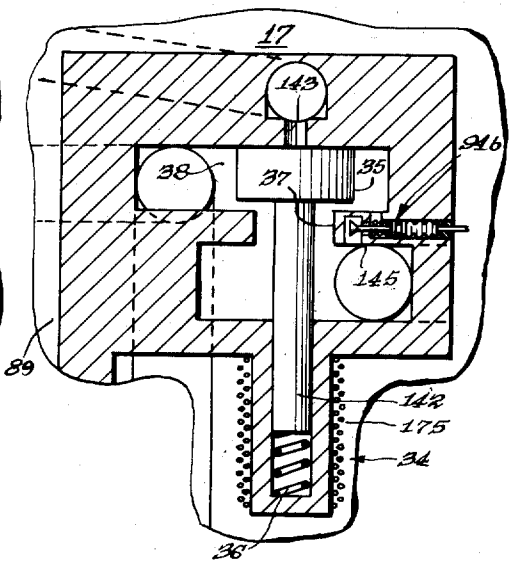


Fig. 6

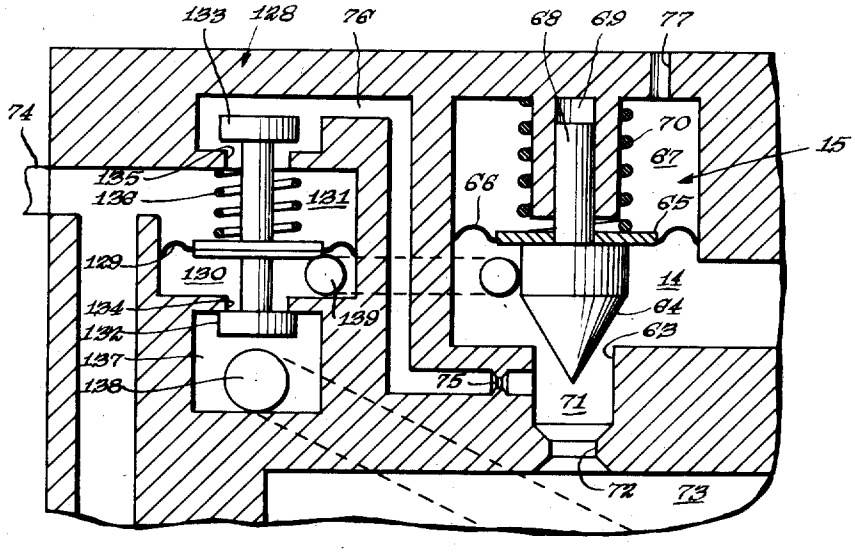


Fig. 7

Inventors
Harold Gold
David M. Straight

By Hill, Sherman, Meroni, Gross & Simpson Attys

United States Patent Office 2,921,569 Patented Jan. 19, 1960

2,921,569

FUEL INJECTION SYSTEM

Harold Gold, Shaker Heights, and David M. Straight, North Olmsted, Ohio

Application December 27, 1957, Serial No. 705,573

38 Claims. (Cl. 123—119)

The invention relates to an improved device for automatically controlling the volumetric rate of flow of liquid fuel to an engine and to a fuel injection system for injecting fuel under pressure into the engine.

The present invention employs certain of the principles and involves a mechanism and system having certain improvements over the devices shown in our copending application entitled "Fuel Injection System," Serial No. 594,532, filed June 28, 1956, now Patent No. 2,876,756, granted March 10, 1959.

In accordance with the present invention, the flow of liquid fuel to an internal combustion engine is controlled by a system which responds to the various factors that affect engine operation. With variance of these factors, the normal engine operation is affected such as by affecting the combustion of the fuel within the engine combustion chambers. The present invention contemplates an improved control system which takes into account a greater number of the factors which affect engine operation and compensates in a more accurate manner for the variance of these factors to achieve optimum control of engine running conditions and optimum engine performance in improved fuel supply to the engine.

The basic fuel supply control system employs a fuel pump which has a delivery output which delivers a supply of fuel in accurate proportion to the speed of the engine. The fuel is delivered through a fuel flow conduit through which the fuel flows to a fuel flow control which delivers fuel to the engine. A control conduit branches from the flow conduit, and a variable orifice is located between the control conduit and the branch conduit. The fuel flow control delivers fuel to the engine in accordance with pressures in said fuel flow conduit and said control conduit.

An object of the invention is to provide a fuel control system employing the above basic components which is provided with a simplified apparatus and method for controlling the rate of fuel delivered under idle conditions.

Another object of the invention is to provide an improved mechanism for installation of the fuel flow control system on an engine.

A further object of the invention is to provide a fuel supply and control mechanism of the type described wherein the variable orifice between the fuel conduit and the control conduit employs an improved simplified metering rod construction for controlling the flow of fuel and the pressure in the control conduit.

Another object of the invention is to provide an improved bellows assembly for controlling the position of the above metering rod to attain increased sensitivity to pressure changes.

Another object of the invention is to provide a simplified and improved apparatus for regulating the fuel pressures in the fuel conduit and control conduit, and in other locations in the system.

A still further object of the invention is to provide an improved arrangement for varying back pressures in the system.

Another object of the invention is to provide an improved mechanism for removing vapor from the system during operation.

Another object of the invention is to provide an improved apparatus for compensating for varying engine volumetric efficiency especially in engines wherein the efficiency "peaks" at mid speed range.

A further object of the invention is to provide an improved system for obtaining an enriched fuel mixture during cold engine operation.

A still further object of the invention is to provide an improved system and apparatus for controlling fuel flow wherein idle air flow during cold engine operation is increased.

An object of the invention is to provide an improved fuel flow control system with improved dynamic response of fuel delivery to the engine with sudden changes in intake manifold pressure.

Another object of the invention is to provide a fuel flow control mechanism which may be used interchangeably on different engines having different displacements, and which is provided with means for adjusting the speed characteristic of the system to accommodate varying engine displacements.

Another object of the invention is to provide a system of the type described wherein a delivery pump carries fuel to a fuel conduit in proportion to engine speed and employs a positive displacement pump with by-pass leakage to maintain pressures on both sides of the pump equal for accurate delivery as a function of speed, and wherein the by-pass leakage around the pump at low pump speeds is reduced.

Another object is to provide a fuel control system wherein fuel discharge and system leakdown during and after engine shutdown are prevented.

A still further object is to provide a fuel control system with an improved mechanism for controlling the rate of fuel delivery during cranking of the engine.

Another object of the invention is to provide a fuel flow system with an improved discharge nozzle regulator assembly operative to control the flow of fuel in accordance with control pressures.

Other objects and advantages will become more apparent from the teachings of the principles of the invention in connection with the disclosure of the preferred embodiments in the specification, claims and drawings, in which:

Figure 1 is a diagrammatic illustration of a fuel injection system in accordance with the present invention;

Figure 2 is an enlarged diagrammatic cross-sectional view illustrating the charge forming mechanism of the present invention;

Figure 3 is a fragmentary cross-sectional view taken generally along line III—III of Figure 2;

Figure 4 is an enlarged diagrammatic cross-sectional view illustrating the fuel flow control mechanism, and the discharge nozzle;

Figure 5 is an enlarged fragmentary sectional view of a valve controlled flow orifice and its accompanying mechanism for accommodating starting conditions of the mechanism;

Figure 6 is another enlarged fragmentary sectional view, similar to Figure 5, but illustrating another form of the orifice, and associated mechanism; and,

Figure 7 is an enlarged fragmentary elevational view of a valve mechanism of Figure 2, the view being enlarged to better illustrate its structure and operation.

In the description, and with reference to the drawings, the structure and operation of the control system and the individual devices will be divided under headings for ease of explanation in accordance with the function and operation of the individual sections of the system.

Installation and fundamental control method

In the illustrated embodiment pump shaft **1** is coupled to engine shaft A so that the pump shaft rotates in an exact fixed proportion to engine speed. For this purpose, the pump shaft carries a pulley **1***a* driven by a belt **1***b* which passes over a pulley **1***c* on the engine shaft A. Pump shaft **1** passes through a suitable seal and enters housing **2**. In housing **2** shaft **1** is coupled to gear pumps **3** and **4**. Pump **3** is of a larger displacement than pump **4**. Fuel enters housing **2** from inlet line **5**. Transfer pump B delivers fuel from tank C via conduit D to line **5** at a moderate and substantially constant pressure. Fuel from line **5** passes through spring-check valve **6** to the inlet chamber **7** of pump **3**. Pump **3** raises the pressure of the fuel to the operating pressure of the system and discharges into chamber **8**.

Chamber **8** is open to the inlet side of pump **4**. Pump **4** discharges into chamber **9**. The excess flow from pump **3** flows through passage **10** and pump by-pass valve **11** and also through passage **12**. Pump by-pass valve **11** functions to maintain the pressure gradient across pump **4** at zero. Although not specifically illustrated, the methods described in the previously referred to application, Patent No. 2,876,756, by which the various internal leakage paths from the discharge side of pump **4** are sealed off, are to be considered to be utilized in the present device. By means of this, the volumetric delivery rate of fuel into chamber **9** is made independent of the fluid pressure in chamber **9** and is a linear function of engine speed over the full speed range of the engine. Pump by-pass valve **11** discharges into passage **13**. Passage **13** joins the inlet chamber **14** of pressure control valve **15**. This arrangement of flow communication, however, is a departure from the communication of flow from the pump by-pass valve in Patent No. 2,876,756. The advantages of this modification will be explained **later.**

The flow delivered into chamber **9** by pump **4** passes through orifice **16** and into chamber **17**. The flow in chamber **17** divides between variable orifice **18** and conduit **19**. The flow through variable orifice **18** discharges into chamber **20**. Chamber **20** communicates directly with passage **21**. Chamber **20** also communicates with passage **22** through orifice **23** and idle mixture control valve **24**. Passage **21** communicates with inlet chamber **14** of pressure-control valve **15**. Passage **21** is of sufficient size to allow the pressure in chamber **20** to be at all times substantially equal to the pressure in chamber **14**. Passage **19** communicates with passage **25** of mounting and distributing bar **26**. Fuel flows from passage **25** through the various orifices **27** and into the various chambers **28** of discharge-nozzle-regulator assemblies **29**. Passages **19** and **25** are of sufficient size to permit the fuel pressure at the upstream side of each orifice **27** to be substantially equal to the pressure at the upstream side of variable orifice **18** (chamber **17**).

The discharge-nozzle-regulator assemblies **29** operate to equalize the pressure downstream of each orifice **27** with the pressure communicated to the chambers **30** of the assemblies **29**. As will be explained, the pressure communicated to the chambers **30** is substantially equal to the pressure in chamber **20** at all engine power levels above idle running. By virtue of this pressure equalization, the pressure drop across each orifice **27** is equal to the pressure drop across variable orifice **18**. The rate of flow discharged by the assembly **29** is thereby functionally related to the ratio of areas of orifice **27** to the open area of variable orifice **18** and to the rate of flow delivered into chamber **17**. As will be explained, the open area of variable orifice **18** is varied by the movement of the bellows assembly **31** in response to the variation of the temperature and pressure of the air in the engine-intake manifold **32**.

Idle mixture control

In the present invention the pressure communicated to chamber **30** of the assemblies **29** is substantially equal to, but at all times slightly lower than, the pressure in chamber **20**. This pressure reduction, which is utilized to obtain mixture enrichment at idle running is obtained in the following manner. Passage **22**, which communicates with passage **20** through orifice **23** and idle mixture control valve **24**, extends into chamber **33** of solenoid actuated valve **34**. When the engine is in operation the solenoid coil is not energized and valve disc **35** is held in the position shown by spring **36**. In this position, port **37** is open permitting flow from chamber **33** to chamber **38**, and escape passage **39** leads from chamber **38** to orifice **40**. Orifice **40** discharges into chamber **7**. Conduit **41** communicates the pressure in chamber **38** to passage **42** in bar **26** and thereby to chamber **30**. Orifice **23** and port **37** are large compared to the escape orifice **40**. The pressure drop across orifice **23** and valve **24** is thereby held to a small value. As a result of the pressure drop across orifice **23** and valve **24** the pressure in chamber **30** is made slightly lower than the pressure in chamber **20**. The reduction in pressure in chamber **30** results in an equal reduction in pressure in chamber **28** of assemblies **29**. The reduction in pressure in chambers **28** causes an increase in pressure drop across orifice **27**. Under the condition of idle running, the pressure drop across orifice **27** is small in which case a reduction in pressure in chamber **28**, although small, causes a significant increase in flow delivery due to increase in pressure drop across orifice **27**. At power levels above idle, the pressure drop across orifices **27** is large compared to the pressure drop across orifice **23** and valve **24** and hence the flow delivery is not affected. Idle mixture control valve **24** is used to vary pressure drop from chamber **20** to passage **22** in order to adjust the idle flow delivery for the optimum idle mixture.

Metering rod and bellows assembly

Variable orifice **18** consists of orifice **43** and contoured plug **44**. Contoured plug **44** is positioned axially in orifice **43** by metering rod **45**. Rod **45** is guided in bearings **46** and **47**. Rod **45** is fastened in a fluid tight and rigid manner to movable bellows head **48**. Metal **bellows 49, 50 and 51** are fastened in a fluid tight manner to head **48**. Chamber **52** encloses the assembly **31**. The three bellows are fastened in a fluid tight manner to wall **53** of chamber **52**. As shown, the three bellows are in coaxial relation with rod **45**. Chamber **54** of assembly **31** communicates with chamber **20** through slot **55** in bearing **46**. Chamber **56** of assembly **31** is sealed with a predetermined mass of dry inert gas. Chamber **57** of assembly **31** communicates with chamber **52** through orifice **58**. Spring **59** augments the spring rate of the metal bellows to obtain the desired spring rate of the assembly **31**.

Chamber **52** communicates with the engine-intake manifold **32** through conduit **60**. A small amount of atmospheric air is bled into chamber **52** through needle valve **61** and passage **62**. Conduit **60** is of sufficient cross-sectional area to permit the pressure in chamber **52** to be at all times substantially equal to the pressure in the engine-intake manifold in spite of the air flow through valve **61**. Valve **61** can be utilized to adjust the idle running speed of the engine. By virtue of the pressure and flow communication with chamber **52**, the assembly **31** is exposed to the pressure of the air in the engine-intake manifold and the temperature of the air flowing into the intake manifold.

Under steady running conditions the air pressure in chamber **57** of the assembly **31** is equal to the pressure in chamber **52**. Thus under steady running conditions bellows **49** acts only as a spring. The object of the addition of bellows **49** is to improve the response of the bellows

assembly to changes in intake manifold pressure. Upon a change in pressure in chamber 52 the new pressure acts immediately on the outside face of head 48. The pressure in chamber 57 will follow the pressure in chamber 52 at a rate determined by the flow resistance of orifice 58 and the compressibility of the air in chamber 57. Until the pressure in chamber 57 equalizes with the pressure in chamber 52, the pressure difference acting on the annular area of head 48 between bellows 49 and 50 creates a driving force on head 48. This added driving force improves the sensitivity of the bellows assembly to pressure changes and quickens the movement of the assembly.

The addition of the air bleed through valve 61 will improve the response of the bellows assembly to changes in intake air temperature. The bellows assembly moves in response to temperature changes through expansion or contraction of the dry inert gas in chamber 56.

Chamber 54 of assembly 31 communicates with chamber 20 and hence with the pressure downstream of variable orifice 18. In the systems described in application Serial No. 450,428, now Patent No. 2,876,755, granted March 10, 1959, and Patent No. 2,876,756, this communication is made with the pressure upstream of the variable orifice. The present modification is made to permit correction for variations in engine back pressure and correction for varying engine volumetric efficiency when the efficiency "peaks" in the mid-speed range. These corrections will be described in later paragraphs.

The contoured plug 44 decreases the open area of variable orifice 18 as metering rod 45 moves toward orifice 43. It may, therefore, be seen that at a fixed engine speed an increase in intake manifold pressure causes an increase in fuel delivery, an increase in inlet air temperature causes a decrease; and an increase in fuel pressure in chamber 20 causes a decrease.

Pressure control valve, back-pressure correction and vapor elimination

The pressure in passage 20 and hence in chamber 54 is controlled by pressure control valve 15. Pressure control valve 15 consists of orifice 63 and conical plug 64. Plug 64 is fastened to diaphragm plate 65. Limp diaphragm 66 is clamped between plug 64 and diaphragm plate 65 and is fastened to the walls of chamber 67, thereby forming a liquid-tight, movable wall between chambers 67 and 14. Cylindrical rod 68 is integral with plug 65 and maintains plug 65 coaxial with and perpendicular to orifice 63. Rod 68 is retained in bore 69. Spring 70 biases plug 64 into orifice 63. Fuel pressure in chamber 14 acting on the annular area of diaphragm 66 (bounded by the wall of chamber 14 and the periphery of orifice 63) creates a force opposite to the spring bias. Fuel pressure in chamber 71 acting on plug 64 also creates a force opposite to the spring bias. Orifice 63 opens into chamber 71. Chamber 71 communicates with chamber 7 through orifice 72 and passage 73. Chamber 71 also communicates with tank return line 74 through orifice 75 and passage 76. Orifice 72 is large compared to orifice 75. Chamber 67 communicates with the atmosphere through vent 77. Atmospheric pressure acting on the full area of diaphragm 66 creates a force in the same direction as the spring bias.

As now described, the pressure in chamber 14 is a function of the axial force balance between the spring bias force and the forces that result from the pressures in chambers 14, 67 and 71. When the engine speed is varied, the flow into valve 15, from pump by-pass valve 11 and variable orifice 18, varies. An increase in flow through valve 15 causes plug 64 to move out of orifice 63. This movement causes compression of spring 70 and hence an increase in spring bias. The increase in spring bias is offset by the increase in upward force that results from the increase in pressure in chamber 71 due to the increase in flow through orifices 72 and 75. This method of modifying the pressure regulation of a spring biased, pressure responsive valve by means of a series of flow restrictions is an application of the principle given in claim 23 of Patent No. 2,876,756 and in said patent a spring-biased, pressure-responsive valve is employed as the series restriction. This more complex flow restriction was required because in that charge forming device the flow into the pressure regulating valve is only the flow by-passed by the bellows-actuated variable orifice. Because of this flow communication the flow range through the pressure regulating valve extended to low values where a simple flow restriction would have no effect. In the present device, the flow into valve 15 is the sum of the flows from variable orifice 18 and the pump by-pass valve 11. The addition of the flow from valve 11 increases the minimum flow sufficiently to allow the use of the simple flow restriction to obtain the required accuracy of pressure regulation.

By virtue of the atmospheric vent to chamber 67, the pressure in chamber 14 will rise and fall directly with variations in atmospheric pressure. This pressure variation causes a corresponding movement of rod 45 and variation of the open area of variable orifice 18. As atmospheric pressure decreases (such as with increasing altitude) the corresponding decrease in pressure in chamber 54 causes a reduction in the open area of variable orifice 18 and hence an enrichment of the charge. This effect is utilized to correct the fuel delivery for the reduction in engine back pressure that occurs with increasing altitude.

By means of the tank return path from chamber 71, vapor that is formed at the discharge from orifice 63 is substantially prevented from returning to the inlet of pump 3. Orifice 75 holds the bleed back flow to the desired limit.

Compensation for variation of volumetric efficiency with speed

As previously described, the pressure in chamber 20 and chamber 54 remains substantially constant as the engine speed is varied (atmospheric pressure being constant). If then, the speed of the engine is varied while intake-manifold pressure, inlet-air temperature and atmospheric pressure remain constant, rod 45 will remain in a fixed position. Hence the open area of variable orifice 18 will remain fixed. As a result of the constancy of variable orifice 18, the fuel delivery varies in direct linear relationship with the rate of flow into chamber 17. By the means that will now be described, the rate of fuel delivery into chamber 17 may be made to vary in either a linear or a non-linear relation with engine speed. By this means the rate of fuel delivery to the engine can be made to vary in either a linear or a non-linear relation with engine speed.

In the case of engines that utilize resonant intake manifolds, there is an effective peak in volumetric efficiency in substantially the mid-speed range. To accommodate this type of engine, the fuel delivery, at constant intake-manifold pressure and intake air temperature, must increase in greater than linear proportion in the lower half of the speed range and increase in less than linear proportion in the upper half of the speed range as the engine speed is varied from low speed to maximum speed. This compensation is provided through variable orifice 79. Variable orifice 79 consists of a contoured plug 78 that is positioned in the orifice 79. Plug 78 is fastened in a fluid-tight manner to limp diaphragm 80 and diaphragm plate 81. Stem 82 is guided in bore 83 to hold plug 78 concentric with and perpendicular to orifice 79. Diaphragm 80 is fastened to the wall of chamber 84 to form a liquid-tight movable wall between chambers 84 and 85. Spring 86 biases diaphragm 80 toward chamber 84. Chamber 84 communicates with chamber 8 through passages 87 and 12. Chamber 85 communicates with chamber 17 through passages 88 and 89. Orifice 79 opens into chamber 90. Chamber 90 communicates with chamber 17 through passages 91 and 89. The passages are of sufficient size so that the pres-

sure in chamber 84 is substantially equal to the pressure in chamber 8 and the pressure in chamber 85 and 90 is substantially equal to the pressure in chamber 17. By virtue of the zero pressure gradient across pump 4, the pressure difference between chambers 8 and 17 is the pressure drop across orifice 16. Thus the pressure difference across diaphragm 80 and the pressure drop across variable orifice 79 is substantially equal to the pressure drop across orifice 16. By virtue of the equality of pressure drops the flow rate contributed to chamber 17 by variable orifice 79 is proportional to the flow rate contributed by pump 4 and to the open area of variable orifice 79. The open area of variable orifice 79 is varied by the movement of diaphragm 80 against spring 86 and is thereby controlled by the rate of flow from pump 4. Thus the flow added into chamber 17 by variable orifice 79 is completely controlled by engine speed. By the proper contouring of plug 78 the variation of flow added to chamber 17 can be adjusted to vary the rate of fuel delivery of the system with speed to match a wide variety of volumetric efficiency speed variations. In the case of engines that exhibit constant volumetric efficiency with speed, variable orifice 79 is eliminated.

Cold-running compensation

The control principle given in claim 21 of Patent No. 2,876,756 is also utilized in the present device to obtain enrichment of the charge during operation with a cold engine. Cold-enrichment variable orifice 92 may be seen to communicate with chambers 8 and 17 in the same manner as this communication is brought to variable orifice 79. Therefore, the flow added by variable orifice 92 is proportional to the flow through orifice 16, the constant of proportionality being equal to the ratio of the open area of variable orifice 92 to the area of orifice 16.

Variable orifice 92 consists of orifice 93 and tapered plug 94. Tapered plug 94 is integral with seal piston 95, rod 96 and spool 97. Metal bellows 98 pushes against spool 97 urging the assembly against spring 99. Bellows 98 communicates with bulb 100 through capillary tube 101, Fig. 1. The bulb, capillary and bellows are sealed full of a suitable liquid. Bulb 100 is inserted in a region indicative of engine operating temperature such as the engine water jacket E.

When the engine is cold, the liquid in bulb 100 contracts causing contraction of bellows 98, Fig. 2. Plug 94 is then drawn out of orifice 93 by spring 99. When the water jacket temperature is raised by operation of the engine, the expansion of the liquid in bulb 100 moves plug 94 into orifice 93, thereby gradually reducing the enrichment flow. When the water jacket temperature approaches the normal limit, plug 94 seats against orifice 93 to cut off the enrichment flow entirely.

Bellows 98 is fastened at its fixed end to piston 102. Piston 102 is urged against shoulder 103 in bore 104 by spring 105. In the event of over temperature of the water jacket, spring 105 takes up the excess expansion of bellows 98 thereby preventing damage to variable orifice 92 or bellows 98.

As may be seen, bellows 98 simultaneously actuates spool 97 and plug 94. Spool 97 moves in annulus 106 to form a flow controlling valve. Annulus 106 communicates with the atmosphere through passage 107. Spool 97 opens annulus 106 to chamber 108. Chamber 108 communicates with passage 62 through passage 109. By the previously described action of bellows 98, spool 97 and annulus 106 provide an automatic valve that provides increased airflow to the engine at idle (throttle F closed) when the engine is cold.

Dynamic response

Upon sudden opening of the engine throttle F, Fig. 1, the pressure in the intake manifold increases very rapidly. The response of fuel delivery to the sudden increase in intake manifold is delayed in inertial and capacitive effects associated with the flow of liquids. In order to obtain good engine acceleration characteristics, it is necessary to compensate for this natural lag. This compensation is obtained in the present device through derivative element 110, Fig. 2.

Derivative element 110 consists of piston 111 operating in bore 112 and sealed against fuel leakage by limp diaphragm 113. Limp diaphragm 113 seals fuel in chamber 114. Chamber 114 communicates with chamber 17 through orifice 115. Fuel pressure in chamber 17 urges piston 111 against spring 116. Spring 116 is retained in chamber 117. Chamber 117 communicates directly with chamber 52 and hence with engine-intake-manifold pressure. Spring 116 maintains the force equilibrium between the higher fuel pressure and the intake manifold pressure that act on opposite sides of piston 111. Spring 116 is so constructed that it maintains the force balance under the condition of lowest intake-manifold pressure when the piston 111 is at substantially the upper end of its stroke (as shown in the drawings). Under the condition of highest intake-manifold pressure, the force balance is maintained when the piston 111 is at the lower end of its stroke. The downward and upward movement of piston 111 with increasing and decreasing intake-manifold pressure causes fuel to be added to or drawn away from chamber 17. This action causes the pressure in chamber 17 to momentarily rise above the steady running pressure when intake manifold pressure rises, and to momentarily fall below the steady running pressure when intake-manifold pressure falls. The momentary excess pressure charge in chamber 17 overcomes the physical lags in delivery of fuel from chamber 17.

The rate of change of pressure in chamber 114, is substantially, instantly equal to the rate of change of intake manifold pressure (or to the derivative of manifold pressure). The rate of flow into or out of chamber 114 in response to pressure variations in chamber 114 is controlled by orifice 115. The magnitude of the pressure pulse created in chamber 17 and passage 25 following a sudden change in intake-manifold pressure can be varied by adjustment of the area of piston 111, the rate of spring 116 and the area of orifice 115. This adjustment may be made to obtain the optimum acceleration characteristics.

Upon a sudden opening of the engine throttle F of large magnitude the sharp rise in intake-manifold pressure acting on bellows assembly 31 causes (through the previously explained action of bellows 49) rod 45 to be momentarily over driven. This over shoot causes shoulder 118 to seat against orifice 43, and momentarily cut-off the by-pass flow from chamber 17. By means of this cut-off action, all flows entering chamber 17 are momentarily delivered to the assemblies 29 alone. The resulting sharp increase in flow discharge permits smooth acceleration following severe throttle manipulations.

Engine displacement compensation

It is a practice in the automotive industry to build engines that are similar in operating characteristics but that differ in piston displacement. One assembly (as encompassed in housing 2) can be utilized interchangeably for such a group of engines if means are provided for adjustment of the linear rate of delivery of fuel into chamber 17 with engine speed. As previously described, a linear delivery is contributed by pump 4. Orifice 119 provides a means whereby a second (adjustable) linear delivery contribution can be made.

Shaft 120 of plug 121 passes through a suitable seal and engages threads in housing 2. Rotation of shaft 120 causes tapered plug 121 to vary the open area of orifice 119. Fuel flows from chamber 8 through passages 12 and 122 to the upstream side of orifice 119 and communicates with chamber 17 through passages 123, 91 and 89. By means of the hydraulic principle previously explained in conjunction with variable orifices 79 and 92,

the flow that passes through orifice 119 is proportional to the flow through orifice 16, the ratio of the two flows being equal to the ratio of the two open orifice areas. Once adjusted, the open area of orifice 119 remains fixed, hence the flow contributed to chamber 17 by orifice 119 is linearly proportional to engine speed. Adjustable orifice 119 can also be used to compensate for manufacturing variations in the displacement of pump 4.

Pump by-pass valve

With reference to valve 11, it was pointed out previously that the valve discharges into passage 13. The pressure difference between passage 10 and passage 13 is equal to the pressure difference between passage 9 and passage 21. Hence, the pressure drop between passage 10 and passage 13 is equal to the pressure drop across orifice 16 plus the pressure drop across variable orifice 18. The pressure difference between sealing annulus 124 and discharge annulus 125 is equal to the pressure difference between passages 10 and 13. Annulus 124 communicates with passage 10 through passage 126 in piston 127. The leakage flow from annulus 124 to annulus 125 is proportional to the pressure difference between them. At low speed conditions, the pressure drop across orifice 16 and across variable orifice 18 is very small. Hence, at low speed conditions the leakage flow from annulus 124 to annulus 125 is very small. It is of advantage to hold this leakage flow small at low speed because the output of pump 3 is then at a minimum.

Shut-down

Upon shut-down, the action of check valve 6, solenoid valve 34, shut-down valve 128, and the inherent cut-off action of the discharge-nozzle-pressure-regulator assemblies 29 cause fuel to be trapped in housing 2, the assemblies 29 and the connecting passages. Immediately following shut-down there is a momentary continuation of flow of fuel through orifice 75 and passage 74 back to tank C. This flow is stopped by shut-down valve 128 when the pressure in chamber 14 drops a small amount below the operating pressure.

Valve 128 is a pressure-responsive, double acting valve. The pressure responsive element, diaphragm 129 forms a liquid-tight movable wall between chambers 130 and 131. Rigidly connected to diaphragm 129 are valve discs 132 and 133. Valve disc 132 coacts with port 134 and valve disc 133 coacts with port 135. Spring 136 biases diaphragm 129 toward chamber 130. Port 134 communicates chamber 130 with chamber 137. Chamber 137 communicates with chamber 17 through passage 138. Port 135 communicates chamber 131 with orifice 75. Chamber 131 communicates directly with passage 74. Chamber 130 communicates with chamber 14 through passage 139.

During operation of the engine, the fuel pressure in chamber 130, communicated from chamber 140 drives diaphragm 129 against spring 136. In this case (as shown in the drawings) valve disc 132 closes off port 134 and valve disc 133 is lifted to open port 135. In this position, the flow of vapor into passage 74 is permitted as previously described. Immediately after the engine speed is reduced to zero, port 135 remains open permitting the pressurized system to bleed down. However, when the pressure in chamber 130 reduces to a predetermined value, spring 136 moves diaphragm 129 toward chamber 130 thereby causing disc 133 to seal off port 135. The same action causes disc 132 to open port 134.

With port 134 open a static pressure equalization is brought about between chambers 17 and 20. This equalization cannot be provided by variable orifice 18 because shoulder 118 normally seats against orifice 43 during shut-down. With the pressures in chambers 17 and 20 equalized, passages 25 and 42 remain at equal pressures. The pressure in chamber 28 must then be equal to or less than the pressure in chamber 30. When the pressures in chambers 28 and 30 are equal there is a closing force that drives valve disc 140 against seat 141 in assemblies 29, Fig. 4. The closing force results from the pressure unbalance at the valve disc 140. Fuel pressure in chamber 30 urges the disc against the seat. In chamber 28 the fuel pressure cannot act on the disc where it seals off the discharge bore.

Starting-flow control

When the engine is started by cranking with a conventional electric-starter motor, the low rotational speed of pumps 3 and 4 during cranking does not provide sufficient pump out-put to raise the system pressure high enough to close port 134 of valve 128 and permit the assemblies 29 to discharge. Solenoid valve 34 and the associated passages provide the means whereby the discharge flow from the assemblies 29 is maintained and controlled during cranking.

Coil 175 of solenoid 34 is connected to the electrical circuit of the starter motor so that the coil is energized when the starter motor is energized. Thus, armature 142 is drawn against spring 36 by the magnetic pull of coil 175 whenever the engine is being rotated by the starter motor. Armature 142 draws valve disc 35 away from orifice 143 and toward port 37. By this action, orifice 143 is opened and port 37 is closed. Orifice 143 discharges into passage 144. Passage 144 communicates with passage 74.

Boost pump B, Fig. 1, delivers fuel to inlet pipe 5 at the normal operating pressure at cranking speeds. Check valve 6, Fig. 2, which is very lightly spring biased, creates only a negligible pressure loss. Thus, during cranking a substantially constant and predetermined fuel pressure is maintained by conventional means in chamber 7. During cranking, fuel flows from chamber 7 through orifice 40, along passage 39 and through orifice 143 into passage 144 from which the fuel returns to tank C, Fig. 1, via passage 74. It will be noted that the direction of flow through orifice 40, Fig. 2, is, during the cranking, the reverse of the direction of flow during engine running. Fuel also flows from chamber 7 through pump 3 to chamber 8, due both to forward leakage and to the small pumping action of pump 3 at cranking speeds. From chamber 8 the fuel flows through pump 4 to chamber 9 also due to forward leakage and to the small pumping action of pump 4 at cranking speeds. Fuel flowing through pump 4 passes through orifice 16 into chamber 17. Fuel may also flow from chamber 8 to chamber 17 through the several auxiliary paths that were previously described.

As previously pointed out in the description of the idle mixture control, orifice 40 is made relatively small in order to satisfy the requirements of the idle mixture control. During cranking, the flow resistance offered by orifice 40 is great compared to the forward flow resistance of pumps 3 and 4 and the associated passages. By virtue of this, fuel from boost pump B, during cranking, reaches chamber 17 with substantially no loss in pressure. Fuel flowing through orifice 40 may suffer a significant pressure loss. Thus during cranking, the fuel pressure communicated to passage 25 from chamber 17 can be made greater than the fuel pressure communicated to passage 42 from chamber 38. The pressure in chamber 38 is determined by the flow resistance of orifice 143 and the rate of flow into chamber 38. The rate of flow into chamber 38 is the flow through orifice 40 plus the auxiliary flow through orifice 145. Orifice 145 by-passes port 37 and is not sealed off by disc 35. Orifices 143 and 145 can be varied independently of orifice 40 to vary the pressure in chamber 38 and thereby vary the rate of fuel delivery during cranking. Thus the idle mixture circuit is not disturbed by variation of the starting control circuit. If the flow delivery during cranking need be varied with engine or atmospheric temperature,

a temperature actuated plug similar to plug **94** can be used in conjunction with either orifice **143** (**94***a*) Fig. 5, or **94***b* with orifice **145**, Fig. 6.

Discharge-nozzle-regulator assemblies

The discharge-nozzle-regulator assemblies **29**, Figs. 2 and 4, operate in accordance with the hydraulic principle set forth in Patents 2,876,755 and 2,876,756. In the present device several important modifications have been made that yield improvement in the following characteristics: accuracy of pressure regulation at very low flow rates, tightness of cut-off and ease of assembly.

The assembly **29**, Fig. 4, is enclosed in housings **146** and **147**. Housing **146** contains a recess **176** which encloses chamber **28**. A seat **141** projects upward from the recess **176**. Housing **147** contains a bore **148** which mates snugly with the outside of a wall **149**. A limp diaphragm **150** is clamped between the top of wall **149** and a clamping surface **151**. The wall **152** of chamber **30** projects perpendicularly from surface **151**. Bore **153** projects from chamber **30** coaxially with wall **152**. By means of the mating fit between bore **148** and wall **149** concentricity is assured on assembly between bore **153**, wall **152**, the wall **149** and discharge orifice **154**, the common axis being perpendicular to the clamping plane of the diaphragm **150**. A disc **140** is made of an elastic material. The disc is fastened to retainer **155** in recess **156**. Diaphragm **150** is fastened to retainer **155** along flange **157** by plate **158** and nut **159**. Stem **160** of retainer **155** fits slidably in bore **153** to maintain disc **140** and plate **158** concentric with and parallel to seat **141**.

The surface of seat **141** is an annulus, the inner circle of the annulus being the bore of orifice **154**. The thickness of the annular surface is preferably small to obtain sufficient deformation of disc **140** with the small seating force that is available at shut-down for fluid-tight shutoff.

The depth of recess **156** and the thickness of disc **139** are proportioned to hold the exposed surface eof disc **140** in substantially the plane of the upper surface of clamping flange **157**. Seat **141** lies in a common plane with the top of wall **149**. Therefore, when disc **141** contacts seat **140**, diaphragm **150** is held flat and unstressed. At low discharge flow rates the lift of disc **141** from seat **140** is very small compared to the outer clamping diameter of diaphragm **150**. Thus the pressure regulation error introduced by diaphragm distortion is very small. This reduction of pressure regulation error is very significant because the pressure drop across orifice **27** is of this relative magnitude at low discharge flow rates.

The mounting sides of housings **146** and **147** are in a common flat plane where the assembly is fastened to bar **26**. Suitable fasteners, not shown, hold assembly **29** against bar **26** and hold housings **146** and **147** together. Chamber **30** communicates with passage **42** through passage **161** and chamber **28** communicates with passage **25** through passage **162**. Passage **161** is sealed against bar **26** by sealing ring **163**. Ring **163** is retained in recess **164** in housing **147**. Orifice **27** is retained in recess **165** in housing **146**. Recess **165** also retains seal ring **166**. Screen **167** is integral with seal ring **166**.

Discharge orifice **154** opens into enlarged passage **168**. Passage **168** preferably penetrates the bore of discharge orifice **154** to reduce the length of the bore to the minimum that is practical. A finite length is necessary to maintain dimensional reproducibility on the diameter of orifice **154**. Passage **168** opens into enlarged passage **169**. Spool **170** engages housing **146** and boss **171** in intake-manifold **32** to form a substantially air-tight seal. Air is bled into passage **168** through passage **172** and orifice **173**. This air bleed serves to atomize the fuel when the discharge flow rate is very low. At high flow rates the fuel discharging through orifice **154** penetrates in a stream directly into the intake manifold. This penetration is improved by the short length of orifice **154** and the expanding walls of passages **168** and **169**. The penetration action is of great importance in the period immediately following sudden large opening of the engine throttle F. In this period the air bleed through orifice **173** is reduced to essentially zero. The penetration of the discharge stream prevents the wetting of the walls of passages **168** and **169** that is otherwise prevented by the air bleed. The time required for droplet emission from the wetted walls would cause a significant delay in engine response to sudden throttle openings.

Spool **170** is preferably constructed of a thermally insulating material to reduce heat absorption of the assemblies **29** after engine shut-down. The air gap provided between the assembly and the intake manifold permits the assemblies to be cooled by natural convection. These considerations are of importance because the temperature of the intake manifold rises very sharply in the initial period following engine shut-down. During shut-down, heat flow from the engine block is not dissipated by the flow of air through the intake manifold as during operation.

Thus, it will be seen that we have provided an improved fuel flow control system which meets the advantages and objectives hereinbefore set forth. It will be understood that while the system is shown as operating to its best advantage with the various components operating in combination with other components, that the principles and features may be utilized with other components taking advantage of their inherent features.

We have, in the drawings and specification, presented a detailed disclosure of the preferred embodiments of our invention, and it is to be understood that we do not intend to limit the invention to the specific forms disclosed, but intend to cover all modifications, changes and alternative constructions and methods falling within the scope of the principles taught by our invention.

We claim as our invention:

1. In a fuel supply system for an engine, a fuel conduit, means for supplying fuel to said conduit at a rate proportional to engine speed, a fixed orifice in said fuel conduit, a control conduit leading off said fuel conduit upstream of said fixed orifice, a variable orifice connecting the control conduit to said fuel conduit and variable to vary the fuel fed to the engine, a variable idle mixture control orifice means in said control conduit, an escape conduit leading from said control conduit downstream of said variable idling mixture control orifice, a fixed orifice in the escape conduit being of a size smaller than said variable idle mixture control orifice whereby the pressure drop across the idle mixture control orifice is small to have minimum effect at running speeds, and fuel flow control means connecting to said fuel conduit and said control conduit and operative to supply fuel to the engine responsive to pressures in said conduits.

2. In a fuel supply system for an engine a fuel conduit, means for supplying fuel to said conduit at a rate proportional to engine speed, a fixed orifice in said fuel conduit, a control conduit leading off said fuel conduit upstream of said fixed orifice, a variable orifice connecting the control conduit to said fuel conduit and variable to vary the fuel fed to the engine, a fixed orifice in said control conduit, and fuel flow control means connecting to both of said conduits downstream of said fixed orifice and operative to supply fuel to the engine responsive to the pressures in said conduits.

3. In a fuel supply system for an engine, a fuel conduit, means for supplying fuel to said conduit at a rate proportional to engine speed, a fixed orifice in said fuel conduit, a control conduit leading off said fuel conduit upstream of said fixed orifice, a variable idle mixture control orifice in the control conduit having a pressure drop thereacross which is small in relation to the drop across said fixed orifice at running speeds and relatively large at idling speeds, and a fuel flow control means connecting to both of said conduits downstream of said fixed and idle orifices and

operative to supply fuel to the engine responsive to pressures in said conduits.

4. In a fuel supply system for an engine, a fuel conduit, means for supplying fuel to said conduit at a rate proportional to engine speed, a fixed orifice in said fuel conduit, a control conduit leading off said fuel conduit upstream of said fixed orifice, a variable orifice connecting the control conduit to said fuel conduit and variable to vary the fuel fed to the engine, a fixed orifice in said control conduit, a variable idling mixture control valve by-passing said fixed orifice in the control conduit, and fuel flow control means connecting to both of said conduits downstream of said fixed orifices and operative to supply fuel to the engine responsive to the pressures in said conduits.

5. A fuel control and supply assembly for an engine comprising a fuel flow supply conduit, means for delivering fuel to said conduit at a rate proportional to the speed of an engine, a control conduit, a variable orifice connecting between said fuel and control conduit and having a movable valve element with a contoured external surface shaped to provide a desired flow with linear movement relative to the orifice, a fixed orifice in said fuel conduit downstream of the control conduit, and fuel flow control means connected to said conduits and supplying fuel to the engine in accordance with pressures in said conduits.

6. A fuel control and supply assembly for an engine comprising a fuel flow supply conduit, means for delivering fuel to said conduit at a rate proportional to the speed of an engine, a control conduit, a variable flow valve means connected between the fuel conduit and control conduit, first means responsive to intake manifold pressure and connected for controlling the opening of the flow valve, second means responsive to change in intake manifold pressure accelerating the change in opening of said valve means whereby a more rapid response in fuel supply change will be obtained, a fixed orifice in said fuel conduit downstream of the control conduit, and fuel flow control means connected to said conduits and supplying fuel to the engine in accordance with pressures in said conduits.

7. A fuel control and supply assembly for an engine comprising a fuel flow supply conduit, means for delivering fuel to said conduit at a rate proportional to the speed of an engine, a control conduit, a variable flow valve means connected between the fuel conduit and control conduit, first means responsive to intake manifold pressure and connected for controlling the opening of the flow valve, second means also responsive to change in intake manifold pressure and augmenting the force of the first means to change the opening of said valve means, a fixed orifice in said fuel conduit downstream of the control conduit, and fuel flow control means connected to said conduits and supplying fuel to the engine in accordance with pressures in said conduits.

8. A fuel control and supply assembly for an engine comprising a fuel flow supply conduit, means for delivering fuel to said conduit at a rate proportional to the speed of an engine, a control conduit, a variable flow valve means connected between the fuel conduit and control conduit, first means responsive to intake manifold pressure and connected for controlling the opening of the flow valve, an expansible bellows having a movable portion connected to said flow valve and operative to change the opening with expansion or contraction, means exposing one surface of the bellows to the engine manifold pressure, a bleed opening through the bellows whereby a change in manifold pressure will cause a force on the bellows which diminishes as the pressure leaks through the bellows and the pressures on both sides equalize, a fixed orifice in said fuel conduit downstream of the control conduit, and fuel flow control means connected to said conduits and supplying fuel to the engine in accordance with pressures in said conduits.

9. A fuel control and supply assembly for an engine comprising a fuel flow supply conduit, means for delivering fuel to said conduit at a rate proportional to the speed of an engine, a control conduit, a variable flow valve means connected between the fuel conduit and control conduit, temperature responsive means connected to said valve means, means defining a chamber housing said temperature responsive means, a passageway communicating between said chamber and the intake manifold of the engine, an air bleed opening into said chamber whereby the temperature responsive means will be exposed to ambient air of the same temperature that enters the engine, and means operatively connected to said conduit and supplying fuel to the engine in accordance with pressures in said conduits.

10. A fuel control and supply assembly for an engine comprising a fuel flow supply conduit, means for delivering fuel to said conduit at a rate proportional to the speed of an engine, a control conduit, a variable flow valve means connected between the fuel conduit and control conduit, pressure responsive means connected to said valve means to control the opening with changes in pressure in an intake manifold of the engine, means defining a chamber to house the pressure responsive means, a passageway communicating between said chamber and the intake manifold of the engine, an air bleed opening into said chamber, an adjustment member for said air bleed opening whereby the air flow into the chamber can be varied to adjust the idling speed of the engine, and means operatively connected to said conduits and supplying fuel to the engine in accordance with pressures in said conduits.

11. A fuel control and supply assembly for an engine comprising a fuel flow supply conduit, means for delivering fuel to said conduit at a rate proportional to the speed of an engine, a control conduit, a variable flow valve means connected between the fuel conduit and control conduit, a temperature responsive bellows connected to said valve, a first pressure responsive bellows connected to said valve, a second pressure responsive bellows connected to said valve, a chamber surrounding said bellows, a bleed passageway through said second bellows communicating with said chamber whereby pressure changes in the chamber will cause an instantaneous but diminishing effect on said second bellows, a passageway between the bellows chamber and the intake manifold of the engine, an air bleed opening into said chamber whereby the temperature responsive means will be exposed to ambient air of the same temperature that enters the engine, an adjustment member for said air bleed opening whereby the air flow into the chamber can be varied to adjust the idling speed of the engine, and means operatively connected to said conduits and supplying fuel to the engine in accordance with pressures in said conduits.

12. A fuel supply mechanism for an engine comprising a fuel flow conduit, means supplying fuel to the conduit in proportion to the speed of an engine, a control conduit branching from the fuel conduit, a variable orifice between the fuel conduit and the control conduit, a fuel flow control connected to deliver fuel to the engine in accordance with pressures in said conduits, a pressure regulator valve opening from said control conduit to a lower pressure and automatically varying in opening with variance in pressure in the control conduit, and means for supplying additional fuel to said control conduit to improve the accuracy of said pressure regulator valve at idling speeds of the engine.

13. A fuel supply mechanism for an engine comprising a fuel flow conduit, a first positive displacement fuel pump in said conduit operated in proportion to the speed of the engine, a second positive displacement pump in series with the first and driven proportional to engine speed, a by-pass valve connected to the second pump output and responsive to pressure differential across said pump to bleed fuel from the pump intake and cause the

output to be accurately proportional to speed, a control conduit branching from the fuel conduit, a variable orifice between the fuel conduit and the control conduit, a fuel flow control connected to deliver fuel to the engine in accordance with pressures in said conduit, a pressure regulator valve opening from said control conduit to a lower pressure and automatically varying in opening with variance in pressure in the control conduit, and a passageway directing the flow of fuel from said by-pass valve to said control conduit to increase the flow through the pressure regulator valve and increase its accuracy.

14. A fuel supply mechanism for an engine comprising a fuel flow conduit, a fuel pump in said conduit, a control conduit branching from the fuel conduit, an orifice between the fuel conduit and the control conduit, a fuel flow control connected to deliver fuel to the engine in accordance with pressures in said conduits, a flow opening from said control conduit to obtain a flow therethrough discharging to an inlet to the fuel pump, and a small vapor preventing bleed orifice between the pump inlet and the flow opening to discharge vapor formed at the flow opening and prevent it from entering the fuel pump inlet.

15. A fuel supply mechanism for an engine comprising a fuel flow conduit, a positive displacement fuel pump in said conduit operated in proportion to the speed of the engine, a fuel tank connected to supply fuel to said pump, a control conduit branching from the fuel conduit, a variable orifice between the fuel conduit and the control conduit, a fuel flow control connected to deliver fuel to the engine in accordance with pressures in said conduits, a pressure regulator valve opening from said control conduit to a lower pressure and automatically varying in opening with variance in pressure in the control conduit, said regulator valve discharging to an inlet to the fuel pump, and a small bleed vapor-preventing orifice between the pump inlet and the regulator valve and leading to the fuel tank to permit the vapor formed at the valve to flow to the fuel tank and prevent it from entering the pump inlet.

16. A fuel supply mechanism for an engine comprising a fuel flow conduit, means supplying fuel to the conduit in proportion to the speed of an engine, a control conduit branching from the fuel conduit, a variable orifice between the fuel conduit and the control conduit, a fluid flow control connected to deliver fuel to the engine in accordance with pressures in said conduits, and means for varying the fuel flow rate in said fuel conduit non-linearly with speed increase to compensate for change in volumetric efficiency of the engine.

17. A fuel supply mechanism for an engine comprising a fuel flow conduit, means supplying fuel to the conduit in proportion to the speed of an engine, an orifice in said fuel conduit, means for controlling fuel flow to the engine in accordance with the pressure in said fuel flow conduit downstream of said orifice, and pressure responsive means connected to operate responsive to pressure differential across said orifice and connected to vary the pressure in the fuel flow conduit downstream of said orifice to obtain fuel flow rates that increase non-linearly with increase in engine speed to compensate for change in volumetric efficiency of the engine with speed change.

18. A fuel supply mechanism for an engine comprising a fuel flow conduit, pump means supplying fuel to the conduit in proportion to the speed of an engine, an orifice in said fuel conduit, means for controlling fuel flow to the engine in accordance with the pressure in said fuel flow conduit downstream of said orifice, means for pressurizing the intake side of said pump equal to the pressure of the discharge side whereby the pump output is accurately proportional to engine speed, a passageway from the intake side of said pump to the downstream side of said orifice, a variable volumetric efficiency compensating valve connected to permit a fuel flow past the pump and the orifice to the fuel conduit, and means opening said volumetric efficiency valve as a function of engine speed non-linearly with speed change to vary the pressure in the fuel conduit downstream of said orifice non-linearly to compensate for variation in volumetric efficiency of the engine at different speeds.

19. A fuel supply mechanism for an engine comprising a fuel flow conduit, pump means supplying fuel to the conduit in proportion to the speed of an engine, a control conduit branching from the fuel conduit, a variable orifice between the fuel conduit and the control conduit controlling the fuel flow rate in said control conduit independent of variations in engine speed, a fuel flow control connected to deliver fuel to the engine in accordance with pressures in said conduits, a cold running enrichment fuel passageway leading into said fuel conduit to supply additional fuel for cold running, means for delivering pressurized fuel to said enrichment passageway, and a temperature responsive valve means in said enrichment passageway and operative to close with increase in engine temperature.

20. A fuel supply mechanism for an engine comprising a fuel flow conduit, pump means supplying fuel to the conduit in proportion to the speed of an engine, a control conduit branching from the fuel conduit, a variable orifice between the fuel conduit and the control conduit controlling the fuel flow in said control conduit independent of variations in engine speed, a fuel flow control connected to deliver fuel to the engine in accordance with pressures in said conduits, an orifice in said fuel conduit, a cold running enrichment fuel passageway leading into said fuel conduit to supply additional fuel for cold running, means for delivering pressurized fuel to said enrichment passageway at a pressure higher than the pressure in said fuel conduit downstream of said orifice, and a temperature responsive valve means in said enrichment passageway and operative to close with increase in engine temperature.

21. A fuel supply mechanism for an engine comprising a fuel flow conduit, means supplying fuel to the conduit in proportion to the speed of an engine, a control conduit branching from the fuel conduit, a fuel flow control connected to deliver fuel to the engine in accordance with pressures in said conduits, and means for automatically decreasing the size of the fuel flow conduit responsive to a signal whereby pressure is momentarily increased to cause said fuel flow control to supply a rapid fuel increase to the engine.

22. A fuel supply mechanism for an engine comprising a fuel flow conduit, means supplying fuel to the conduit in proportion to the speed of an engine, a control conduit branching from the fuel conduit, a fuel flow control connected to deliver fuel to the engine in accordance with pressures in said conduits, and pressure responsive means connected to the intake manifold of the engine and connected to said fuel conduit and operative to automatically and instantaneously cause a change in pressure in said fuel conduit without directly affecting the pressure in said control conduit causing an immediate increase in the fuel supplied to the engine by said fuel flow control with an increase in intake manifold pressure.

23. A fuel supply mechanism for an engine comprising a fuel flow conduit, means supplying fuel to the conduit in proportion to the speed of an engine, a control conduit branching from the fuel conduit, a fuel flow control connected to deliver fuel to the engine in accordance with pressures in said conduits, a fuel reservoir connected to supply fuel directly to said fuel conduit, and pressure responsive means connected to the intake manifold of the engine and connected to cause a flow of fuel from said reservoir to said conduit with acceleration of the engine to improve the dynamic response.

24. A fuel supply mechanism for an engine comprising a fuel flow conduit, means supplying fuel to the conduit in proportion to the speed of an engine, a control conduit branching from the fuel conduit, a fuel flow control

connected to deliver fuel to the engine in accordance with pressures in said conduits, a chamber opening into said fuel conduit, a pressure balanced movable piston in said chamber exposed to the fuel on one side and movable toward the fuel conduit to discharge fuel from the chamber into the fuel conduit, a biasing means urging the piston toward the conduit, and means connecting the chamber to expose the other side of the piston to the pressure of the intake manifold of the engine whereby sudden decreases in pressure will cause a rapid dynamic response in increased fuel supply to the engine.

25. A fuel supply control system for an engine comprising in combination a fuel flow conduit for supplying and controlling the flow of fuel to an engine, pump means for supplying fuel to said conduit in proportion to the speed of the engine, means for pressurizing the inlet side of said pump means, a pressure drop orifice in said conduit, fuel flow control means for supplying fuel to the engine in accordance with pressure in said fuel flow conduit, a displacement compensating passageway extending around said pump means and connected to the pump inlet and to said fuel conduit downstream of said orifice to vary the pressure in said conduit, a displacement compensation valve in said passageway, and means for adjusting said valve to a fixed opening whereby the quantity of fuel flowing in said fuel conduit is affected linearly proportional to speed and as a function of the adjustment setting of said valve to use the system for engines of different displacement.

26. A fuel supply control system for an engine comprising in combination a fuel flow conduit for supplying and controlling the flow of fuel to an engine, pump means for supplying fuel to said conduit in proportion to the speed of the engine, a control conduit branching from the fuel conduit, a fuel flow control connected to deliver fuel to the engine in accordance with pressures in said conduits, a displacement compensation passageway connected to said fuel conduit, a displacement compensation valve in said passageway, and means for adjusting said valve to a fixed opening whereby the quantity of fuel flowing in said fuel conduit is affected linearly proportional to speed and as a function of the adjustment setting of said valve to use the system for engines of different displacement.

27. A fuel supply control system for an engine comprising in combination a fuel flow conduit for supplying and controlling the flow of fuel to an engine, a first pump in said fuel flow conduit delivering fuel proportional to engine speed, a second pump in said fuel flow conduit receiving fuel from the first pump and having a positive displacement, said second pump being driven by the engine and having a speed which is a linear function of engine speed, a pressure responsive valve communicating with the discharge side and intake side of said second pump and responsive to pressure differential and removing fuel from the intake side and holding the pressures equal whereby the output of the second pump is accurately proportional to engine speed, a fixed orifice downstream from said second pump, and a variable orifice downstream from said second pump, said orifices being of a size with respect to pump discharge to have a very small pressure drop at low engine speed to reduce the pressure differential between the discharge and intake of said second pump at low engine speeds to reduce the amount of fuel which by-passes said second pump through said pressure responsive valve.

28. A fuel supply control system for an engine comprising in combination a fuel flow conduit for supplying and controlling the flow of fuel to an engine, means supplying fuel to the conduit in proportion to the speed of an engine, a control conduit branching from the fuel conduit, a variable orifice between the fuel conduit and the control conduit, means closing said variable orifice when said engine is stopped, a flow control supplying fuel to the engine as a function of pressures in said conduits and stopping the flow when the pressure in the control conduit is equal to that in the fuel conduit, passageways from the control conduit, means automatically opening said passageways when the engine is stopped, and means for equalizing the pressure in the fuel conduit to that in the control conduit when the engine is stopped to cause said fuel flow control to prevent the flow of fuel to the engine.

29. A fuel supply control system for an engine comprising in combination a fuel flow conduit for supplying and controlling the flow of fuel to an engine, means supplying fuel to the conduit in proportion to the speed of an engine, a control conduit branching from the fuel conduit, an orifice between the fuel conduit and the control conduit, means opening said orifice when said engine is stopped, flow control means responsive to pressures in said conduits and operative to prevent the flow of fuel when the pressure in the fuel conduit drops to a predetermined level relative to pressures in the control conduit, and means automatically venting the system when the engine is stopped to cause said flow control means to prevent the flow of fuel to the engine.

30. A fuel supply control system for an engine comprising in combination a fuel flow conduit for supplying and controlling the flow of fuel to an engine, means supplying fuel to the conduit in proportion to the speed of an engine, a control conduit branching from the fuel conduit, a variable orifice between the fuel conduit and control conduit, means closing said variable orifice when said engine is stopped, flow control means operative to deliver fuel to the engine as a function of pressures in said conduits and to stop flow when the pressure equalizes in the fuel conduit and the control conduit, a bleed orifice from the control conduit, a pressure relief passageway leading from said fuel conduit to said control conduit, a bleed shutoff valve in said control passageway in series with the bleed orifice, and means responsive to control conduit pressure operative to close said pressure relief passageway and open said bleed shutoff valve during engine operation and to close the bleed shutoff valve and open the pressure relief passageway when the engine is stopped to stop flow of fuel to the engine by operation of the flow control means.

31. A fuel supply control system for an engine comprising in combination a fuel flow conduit for supplying and controlling the flow of fuel to an engine, positive displacement pump means for supplying fuel to said conduit in proportion to the speed of the engine and driven at a speed proportional to engine speed, a control conduit branching from the fuel conduit, a fuel flow control connected to deliver fuel to the engine in accordance with pressures in said conduits, and means for changing the pressure in said control conduit during engine cranking for increasing fuel delivered by said fuel flow control.

32. A fuel supply control system for an engine comprising in combination a fuel flow conduit for supplying and controlling the flow of fuel to an engine, a control conduit, valve means between the conduit and control conduit whereby a lower pressure is established in said control conduit, means delivering fuel to the engine proportional to pressures in said fuel conduit and said control conduit positive displacement pump means for supplying fuel to said conduit in proportion to the speed of the engine and driven at a speed proportional to engine speed, a booster pump delivering fuel to the inlet of said pump means to supply pressure for starting the engine when said pump means operates at low cranking speeds, a variable idle mixture orifice in said control conduit, an escape orifice leading from said control conduit downstream of said idle mixture orifice and communicating with the intake to said pump means, a relief starting enrichment valve having a valve port between said escape orifice and said idle mixture orifice, and means to open the enrichment valve permitting the escape of fuel from the booster pump to flow through said enrichment valve during starting and

lowering pressure in said control conduit to increase fuel delivery to the engine.

33. A fuel supply control system for an engine comprising in combination a fuel flow conduit for supplying and controlling the flow of fuel to an engine, positive displacement pump means for supplying fuel to said conduit in proportion to the speed of the engine and driven at a speed proportional to engine speed, a booster pump delivering fuel to the inlet of said pump means to supply pressure for starting the engine when said pump means operates at low cranking speeds, a control conduit branching from the fuel conduit, a fuel flow control connected to deliver fuel to the engine in accordance with pressure in said fuel conduits and pressure at one end of said control conduit, a variable idle mixture orifice in said control conduit, an escape orifice leading from said control orifice downstream of said idle mixture orifice and communicating with the intake to said pump means, a relief starting enrichment valve having a valve port between said escape orifice and said idle mixture orifice, means to operate the valve permitting the escape of fuel from the booster pump flowing through said escape orifice during starting, said relief valve also operative to close the control conduit between said idle mixture orifice and said relief valve port whereby said fuel flow control is exposed to control conduit pressure between said escape orifice and said enrichment valve, and a small by-pass port around said relief valve feeding fluid pressure from the idle mixture orifice to said one end of the control conduit.

34. A control system in accordance with claim 33 wherein a heat responsive valve member is located in the opening of at least one of said ports to determine its opening in accordance with engine temperatures.

35. A fuel supply mechanism for an engine comprising a fuel flow conduit, means supplying fuel to the conduit in proportion to the speed of an engine, a control conduit branching from the fuel conduit, a fuel flow control connected to deliver fuel to the engine in accordance with pressures in said conduits, a closed housing having a limp diaphragm thereacross clamped at its edge dividing the housing into a first chamber and a second chamber with the first chamber exposed to the pressure of said control conduit and the second chamber exposed to the pressure of the fuel conduit, a valve seat in said second chamber lying in a plane defined by the clamped edges of said diaphragm, and a valve closing member supported by the diaphragm in the plane of said diaphragm edge to engage the valve seat when the diaphragm is in unstressed condition.

36. In a fuel supply system for an engine including a fuel flow conduit, means supplying fuel to the conduit in proportion to the speed of an engine, a control conduit branching from the fuel conduit, a fuel flow control connected to deliver fuel to the engine in accordance with pressures in said conduits comprising a closed housing having a limp diaphragm thereacross clamped at its edge dividing the housing into a first chamber and a second chamber with the first chamber exposed to the pressure of said control conduit and the second chamber exposed to the pressure of the fuel conduit, a valve seat in said second chamber lying in a plane defined by the clamped edge of said diaphragm, a valve closing member supported by the diaphragm in the plane of said diaphragm edge to engage the valve seat when the diaphragm is in unstressed condition, and means supporting a valve closing member and having an annular opening to fit over said seat with a closing member recessed in said supporting means and carried in the plane of said diaphragm clamping means when engaging said seat.

37. A fuel supply mechanism for an engine comprising a fuel flow conduit, means supplying fuel to the conduit in proportion to the speed of an engine, a control conduit branching from the fuel conduit, a fuel flow control connected to deliver fuel to the engine in accordance with pressures in said conduits comprising a closed housing having a limp diaphragm thereacross clamped at its edge dividing the housing into a first chamber and a second chamber with the first chamber exposed to the pressure of said control conduit and the second chamber exposed to the pressure of the fuel conduit, a valve seat carried by said diaphragm, an intake manifold for the engine, a passageway leading from said valve seat to said manifold, and a spacer member having a flow path therethrough forming part of said passageway and formed of insulating material and consisting of the only heat flow path between said manifold and diaphragm housing.

38. The method of regulating a supply of fuel to an internal combustion engine which comprises the steps of establishing a path for flow of fuel from a fuel source to the intake of an engine, restricting the area of the flow path at a given point therealong to a predetermined area, delivering the fuel along the flow path at a rate proportional to the speed of operation of the engine, providing a flow path around said restricted area and permitting flow therethrough as a function of the engine speed and as a function of the volumetric efficiency of the engine to supply fuel to the flow path downstream of the restricted area, and delivering fuel up to the engine in accordance with flow conditions in said flow path downstream of said restricted area.

References Cited in the file of this patent

UNITED STATES PATENTS

2,696,405	Noon	Dec. 7, 1954
2,785,669	Armstrong	Mar. 19, 1957
2,803,233	Demtchenko	Aug. 20, 1957