United States Patent

Jackson

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[54] **FUEL INJECTION SYSTEMS**

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[52] **U.S. Cl.** ....**123/139 AX,** 123/119 R, 123/139 AW
[51] **Int. Cl.** **F02m 69/00**
[58] **Field of Search**............123/119, 139 AW, 139 AX, 140, 123/140 MC, 179 A

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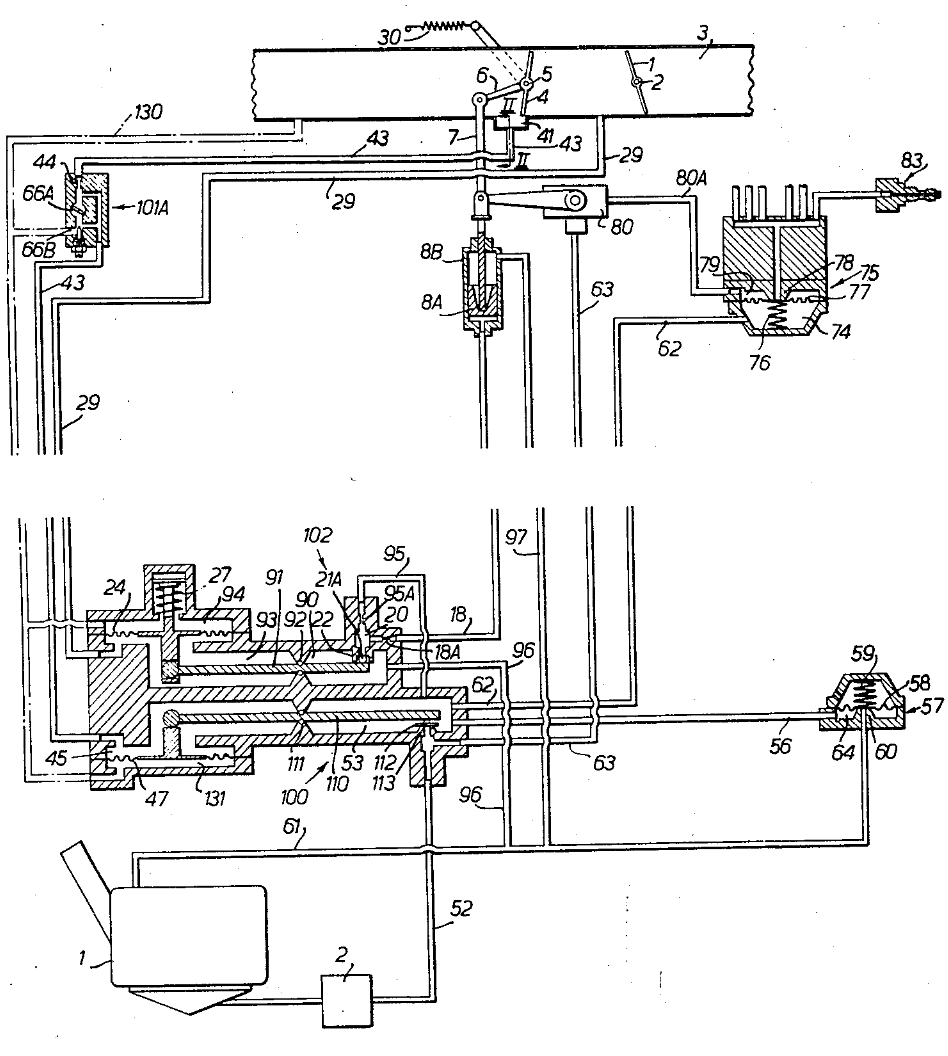
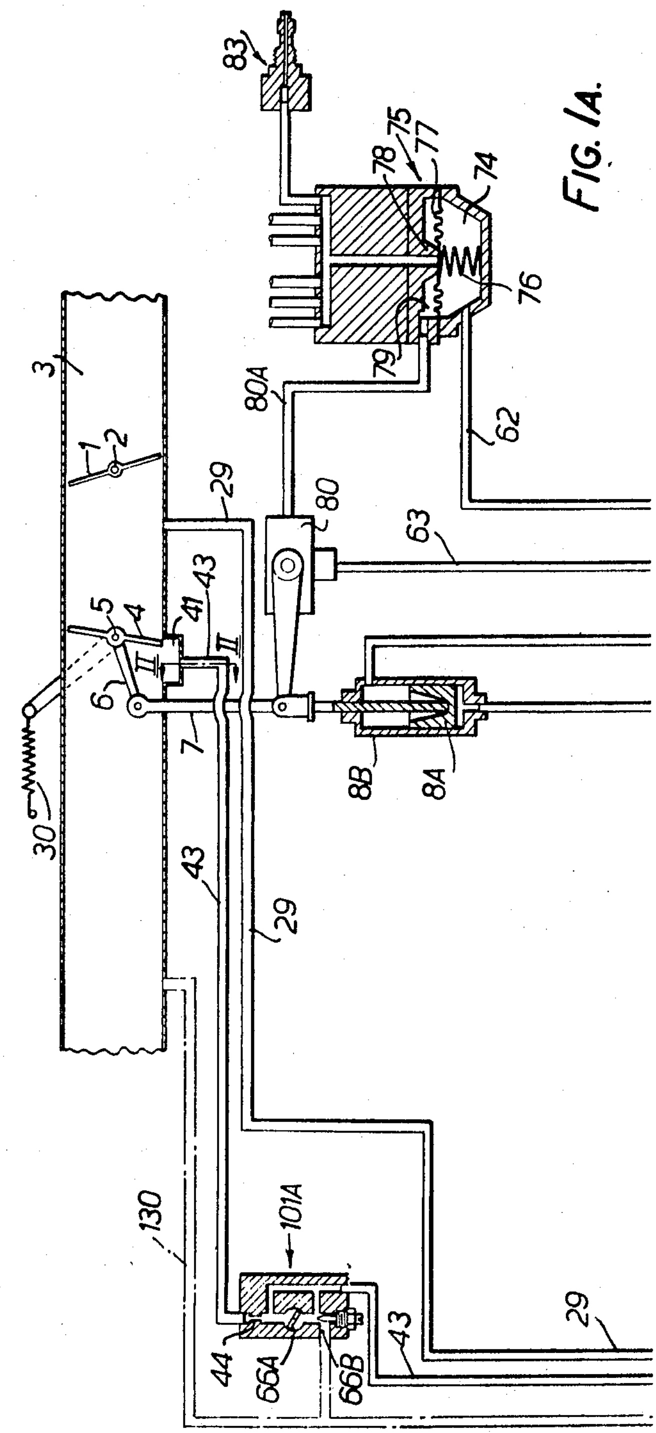
Primary Examiner—Laurence M. Goodridge
Attorney—Holcombe, Wetherill & Brisebois

[57] **ABSTRACT**

A fuel injection system for an internal combustion engine, including a fuel motoring device and/or a fuel pressurizing device. The or each device operates in response to adjustment of an air valve located in the engine air intake conduit (for example, upstream of the throttle valve), such adjustment being effected by a control mechanism in the following manner. The air valve produces a control pressure differential in the air intake conduit, which is sensed by the control mechanism. Any change in the pressure differential from a predetermined control value (caused, for example, by an increase in the engine air intake) causes the control mechanism to adjust the fuel flow path which feeds the fuel injector devices. The air valve is connected to the fuel control circuit and the position of the air valve is thereby adjusted to return the control pressure differential to the predetermined control valve. This adjustment is accompanied by a change in the fuel flow or pressure of fuel flow to the injector devices.

28 Claims, 12 Drawing Figures




83
75
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80A
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II
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66A
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43
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FIG. 1A.

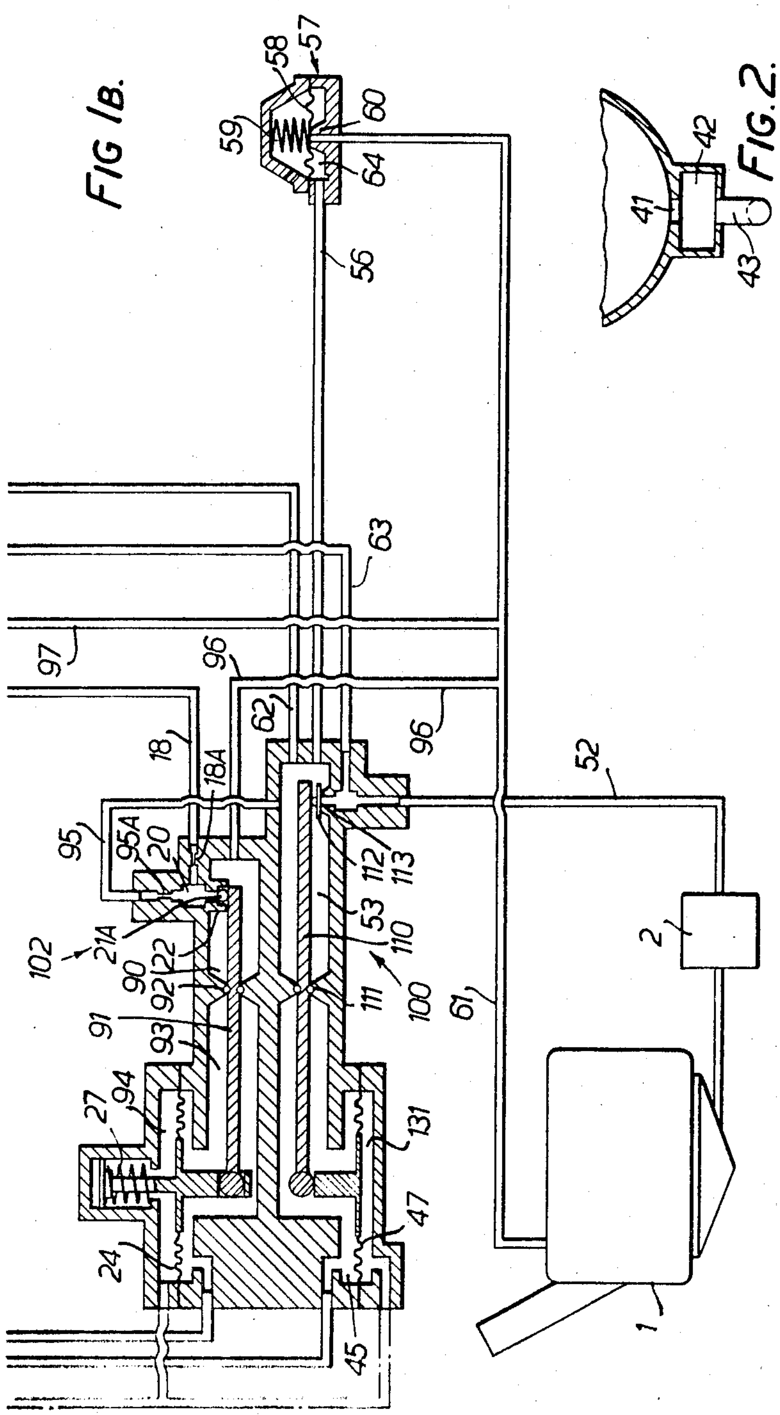

FIG. 1B.

FIG. 2.

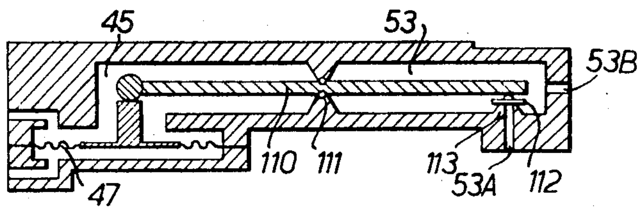

FIG. 3.

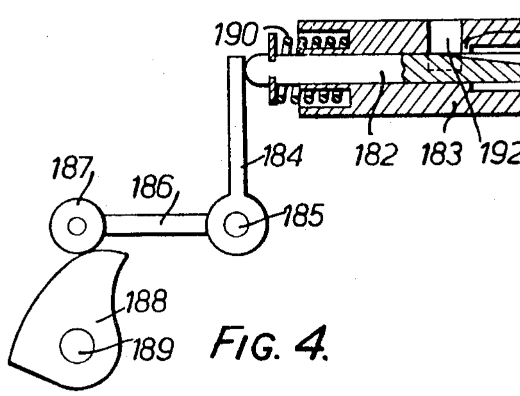

FIG. 4.

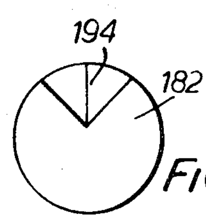

FIG. 5.

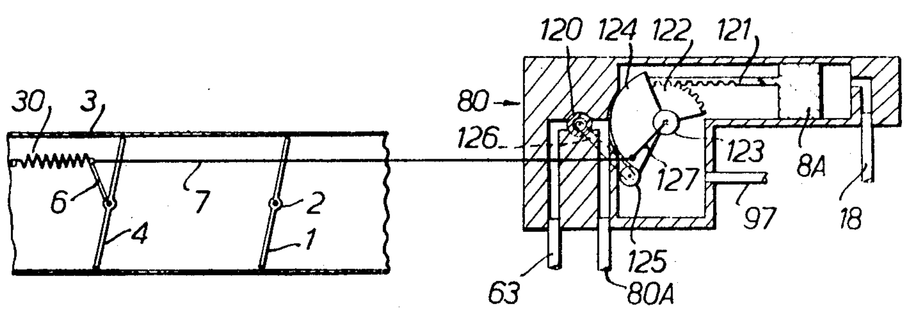

FIG. 6.

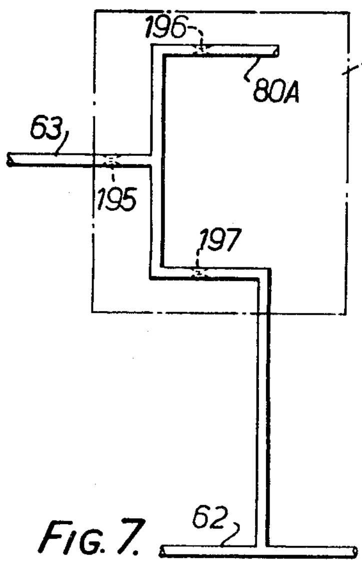

FIG. 7.

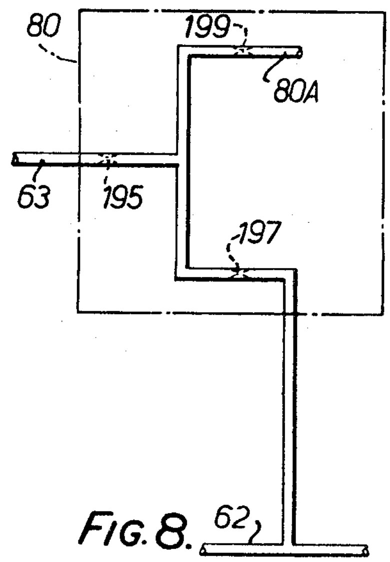

FIG. 8.

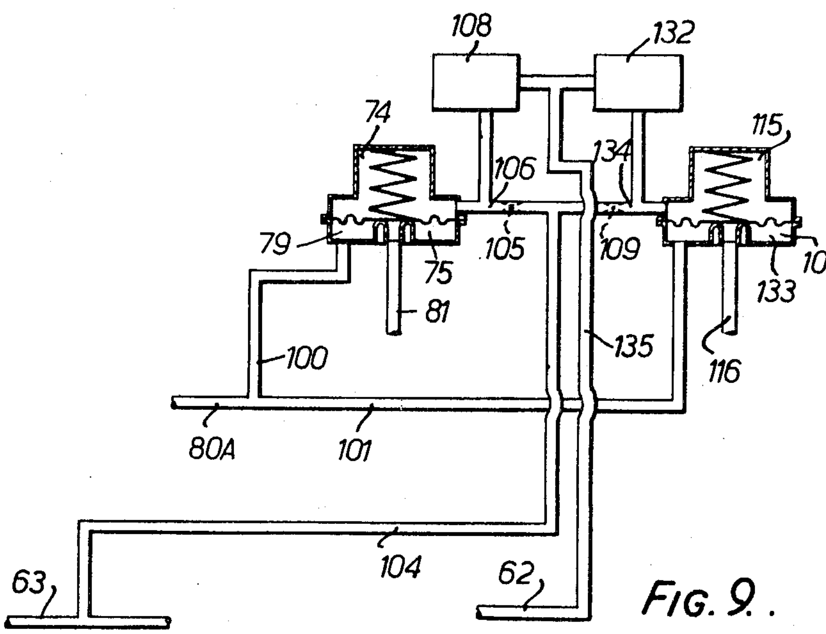

FIG. 9.

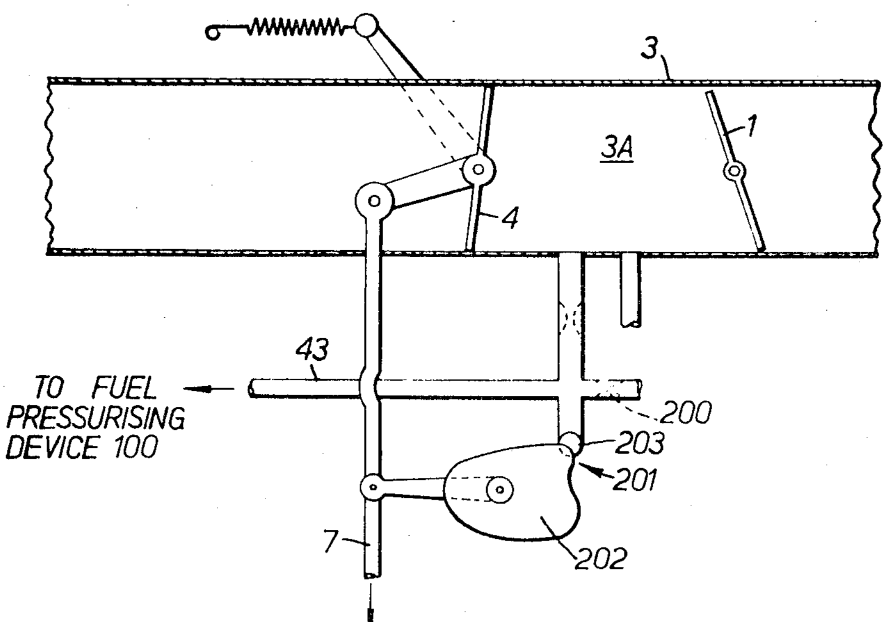
3
3A
1
4
43
TO FUEL PRESSURISING DEVICE 100
200
203
201
202
7
TO AIR VALVE CONTROL MECHANISM

FIG. 10.

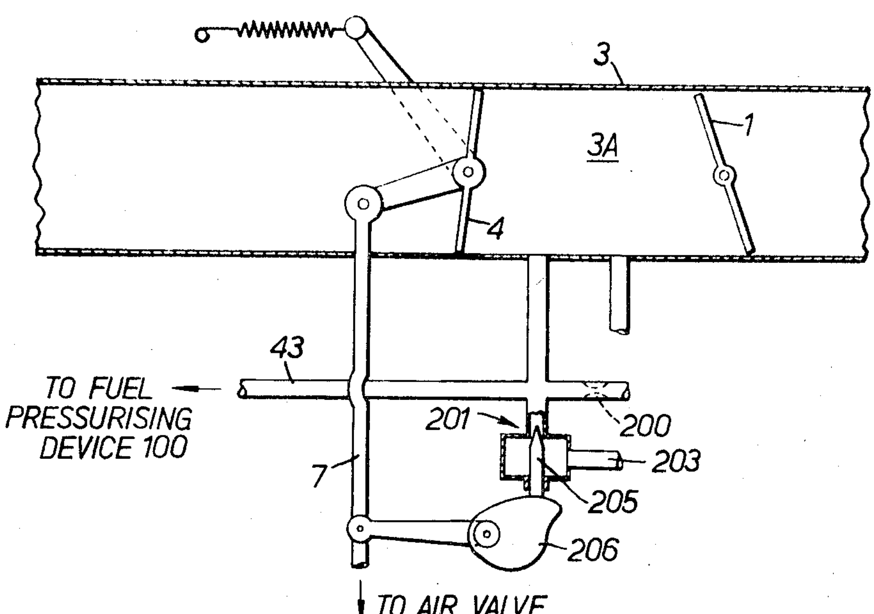
3
3A
1
4
43
TO FUEL PRESSURISING DEVICE 100
201
200
203
205
206
7
TO AIR VALVE CONTROL MECHANISM

FIG. 11.

FUEL INJECTION SYSTEMS

The invention relates to fuel injection systems for internal combustion engines.

The invention provides a fuel injection system for an internal combustion engine, including a fuel flow path, at least one fuel injector device and a fuel control circuit connected to receive fuel from the flow path, and a fuel metering device connected in the flow path and operable to vary fuel flow to the injector device(s), in response to adjustment of an air valve which is located in the engine air supply path to produce a control pressure differential over a portion of the air supply path, the air valve being adjustable to vary the control pressure differential in response to variation in the fuel pressure in the fuel control circuit, the system also including a signal valve mechanism operable in response to a value of control pressure differential other than a predetermined value to vary the pressure in the fuel control circuit and thereby adjust the air valve to maintain the control pressure differential substantially constant at the said predetermined value. The system may also include a fuel pressurizing device connected in the flow path and operable, in response to adjustment of the air valve, to vary the pressure at which fuel flows to the injector device(s).

The invention also provides a fuel injection system for an internal combustion engine, including a fuel flow path, at least one fuel injector device and a fuel control circuit connected to receive fuel from the flow path, and a fuel pressurizing device connected in the flow path and operable to vary the pressure at which fuel flows to the injector device(s), in response to adjustment of an air valve which is located in the engine air supply path to produce a control pressure differential over a portion of the air supply path, the air valve being adjustable to vary the control pressure differential in response to variation in the fuel pressure in the fuel control circuit, the system also including a signal valve mechanism operable in response to a value of control pressure differential other than a predetermined value to vary the pressure in the fuel control circuit and thereby adjust the air valve to maintain the control pressure differential substantially constant at the said predetermined value.

The fuel pressurizing device may be a pressure-responsive device exposed to the control pressure differential to an extent which varies with adjustment of the air valve. The pressurizing device may, for example, be operable to bypass fuel from the flow path in dependence on the adjustment of the air valve, the system including means operable to supply fuel to the flow path in excess of the engine operating requirements.

The air valve may be located in the engine air supply path upstream of the customary throttle valve.

When the system includes a fuel pressurizing device as defined above, it may also include a fuel pressure adjustment mechanism by which the pressurizing device can be operated independently of the air valve. The pressure adjustment mechanism may be responsive to engine air intake, as represented by, for example, air pressure in the engine air supply path downstream of the customary throttle valve. The adjustment mechanism may, for example, be responsive to the engine air intake condition which indicates that the engine is developing maximum power, to cause operation of the pressurizing device to increase fuel pressure.

When the system includes a fuel metering device, this may include a variable metering orifice which is connected in the fuel flow path to supply fuel to the injector device(s) and the area of which is adjustable in response to adjustment of the air valve. Alternatively the fuel metering device may include a variable metering orifice which is connected in the fuel flow path to bypass fuel from the injector device(s) and the area of which is adjustable in response to adjustment of the air valve.

By way of example, fuel injection systems constructed in accordance with the invention will be described with reference to the accompanying drawings, of which:

FIGS. 1A and B is a diagram of a system constructed in accordance with the invention;

FIG. 2 is a view on the line II—II of FIG. 1;

FIG. 3 is a view of a component of the system shown in FIG. 1;

FIG. 4 is a diagrammatic illustration of a control valve suitable for use in the system shown in FIG. 1;

FIG. 5 is a view, on an enlayed scale, of part of FIG. 3 in the direction of the arrow V;

FIG. 6 illustrates a suitable arrangement of certain of the components of the system shown in FIG. 1, and

FIGS. 7 and 11 illustrate modifications of the system shown in FIG. 1.

In the system shown in FIG. 1, fuel is drawn from a tank **1** and supplied by any suitable form of pump **2**, for example an electric gear pump, to a supply conduit **52**. Fuel passes from the conduit **52** to a further supply conduit **63** at a pressure determined by a fuel pressurizing mechanism **100**, excess fuel being returned, via a valve **112, 113** and chamber **53** in mechanism **100**, a conduit **56**, a relief valve **57** and a conduit **61** to the tank **1**. The supply conduit **63** leads to a metering valve **80** which supplies fuel, via a conduit **80A** to a distributor unit **75** from which the fuel injector nozzles **83** are fed.

As mentioned above, the mechanism **100** controls the pressure at which fuel is supplied to the metering valve **80**, this control being effected, as will be described below, in dependence on engine air intake, and the metering valve **80** determines the amount of fuel supplied to the nozzle **83** this control being effected, as will be described below, by a signal valve mechanism **102**, also in dependence on engine air intake.

The system shown in FIG. 1 also includes a fuel/air mixture enrichment valve **101A** operable to provide an enriched fuel/air ratio when desired, for example when the engine is cold. This component will also be described below.

The control of the metering valve **80** in the present system will now be described. Control of the metering valve **80** is effected by a servo-mechanism in dependence on engine air intake and, in particular, by a servo-mechanism which operates to maintain a constant pressure differential across a variable restrictor located in the engine air intake path. Initially, in the following description, it will be assumed that conduit **130** (shown in dotted lines in FIG. 1) is absent.

The engine air intake conduit is indicated by the reference numeral **3** and feeds air to the engine in the direction left to right as seen in FIG. 1. The conduit **3** includes the customary throttle valve **1** which is mounted on a spindle **2** extending across the conduit **3** and which is manually operated in a conventional manner. The conduit **3** also includes, upstream of the throttle valve **1**, an air valve **4** which is mounted on a spindle **5** and which is biased towards a closed position by a spring **30**. The air valve **4** is operated by a lever **6** connected to a control lever **7** which is also connected to the fuel metering unit **80**.

The lever **7** is also coupled to a piston **8A** located in a cylinder **8B** which, on the other side of the piston to the lever **7** is connected by a conduit **18** including a restrictor **18A** to a chamber **20** in the signal valve mechanism **102**. Communication between the chamber **20** and a further chamber **90** in the signal valve mechanism **102** is controlled by a ball valve **21A** coacting with a seat **22**. A control rod **91** extending from the chamber **90** through a seal **92** and into a chamber **93** couples the ball valve **21A** to a diaphragm **24** which separates the chamber **93** from a further chamber **94** (open, in the absence of conduit **130**, to atmosphere). The rod **91** is capable of rocking movement in the seal **92** and a spring **27** located in chamber **93** acts on the diaphragm **24** and hence on rod **91** to urge the ball valve **21A** away from the seat **22**. A conduit **29** joins chamber **93** to the air intake conduit **3** between the valves **1** and **4**, and a conduit **95** including a restrictor **95A** connects the chamber **20** to the chamber **53** of the pressurizing mechanism **100**.

It was mentioned above that chamber **53** receives excess fuel from the supply conduit **52** and is connected, via relief valves **57** to the fuel tank **1**. The chamber **53** is, in fact, connected to a chamber **64** of the relief valve **57**, and the chamber **64** can communicate, under the control of a diaphragm **58**, with the conduit 61 leading back to the fuel tank 1. The diaphragm 58 is loaded, by a spring 59, against a valve seat 60 separating chamber 64 from conduit 61, and thereby maintains a substantially constant fuel pressure in chamber 64 and hence in chamber 53.

In operation of the system, the air valve 4 is urged towards a closed position by a spring 30. When the throttle valve 1 is opened (the air valve 4 being in the closed position) there is created a depression in the conduit 29 which draws down the diaphragm 24, so closing the ball valve 21A. The substantially constant pressure determined by the relief valve 57 is then applied fully, via conduit 18, on the piston 8A causing the latter to move upward (as seen in FIG. 3) and, through lever 7 to open the air valve 4. Any leakage of fuel across the piston 8A is returned to the tank 1 through conduit 97. The opening of air valve 4 reduces the depression in conduit 29 and, through diaphragm 24 opens the ball valve 21A allowing fuel to leak from chamber 20 into chamber 90 and to be returned to the tank 1 via conduit 96. The fuel pressure acting on piston 8A is thereby reduced and the piston moves downwards (as seen in FIG. 3) to close the air valve 4. In this manner, the position of the air valve 4 adjusts to maintain a substantially constant depression in that portion of the conduit 3 between the valves 4 and 1, the depression being determined by the setting of the control mechanism 102 and, in particular, by the strength of the spring 27. It is to be noted that, provided the pressure in chamber 93 required to drive the ball valve 21A fully open is less than the substantially constant relief valve pressure, the strength of spring 30 and the effects of friction in the piston 8A, the linkages 5, 6, 7 etc., are in no way effective in altering the constant depression in the conduit 3 by any substantial amount. The value of the restrictor 95A is chosen to give a desired opening speed to the ball valve 21A.

The air valve 4 is so coupled to the fuel metering valve 80 that, as the air valve 4 opens, more fuel is fed by the metering valve to the injector devices 83. Further description of the metering valve 80 will be given below.

The pressurizing mechanism 100 will now be described. This mechanism 100 is not essential to the functioning of the system but, when present, it operates to increase the pressure of fuel supplied to the metering valve 80 as the air flow through conduit 3 increases. The conduit 3 includes a closed end slot 41 which communicates with a conduit 43 (see FIG. 2) leading, via a restrictor 44, to a chamber 45 in the control mechanism 100. A diaphragm 47, bounding the chamber 45, is coupled to one end of a central rod 110 (similar to rod 91 in the signal valve mechanism 102) which extends through a seal 111 into the chamber 53 and carries, at its other end, a pressure control valve member 112. The valve member 112 cooperates with a sealing 113 to control fuel flow from the supply conduit 52 into the chamber 53. The rod 110 is capable of rocking movement in the seal 111 and movement of the valve member 112 is controlled, through the rod, by the diaphragm 47. The chamber 53 is connected, by conduit 56 to the relief valve 57, as described above, the chamber 53 thereby being pressurized to the substantially constant relief valve pressure.

When the engine is not running, atmospheric pressure exists throughout the air intake conduit 3, and hence in the chamber 45. A chamber 131 on the other side of the diaphragm 47 to chamber 45 is also, in the absence of conduit 130, exposed to atmospheric pressure so that there is no pressure differential across the diaphragm. The pressure in supply conduits 52 and 63 is then the same as that in chamber 53. When the engine is running with its air consumption at a minimum (which is the idling mode of operation) the position of the air valve 4 is such that the right hand end of slot 41 lies just on the right hand side of air valve 4 (this position being shown in FIG. 3). As a result, a small proportion of the constant depression developed in conduit 3 between the valves 1 and 4 is applied to conduit 43.

The enrichment valve 101A (which will be described below) is normally open and, for the present, it is sufficient to state that, under these circumstances and in the absence of conduit 130, atmospheric air can pass via restrictors 66A and 66B in the valve 101A into the conduit 43 so weakening the depression signal applied to diaphragm 47. The weakened depression signal applied to diaphragm 47 acting through rod 110 urges the valve member 112 towards the seat 113 and, as a result, the fuel pressure in supply conduits 52 and 63 rises until equilibrium is restored. As the air consumption of the engine increases, air valve 4 opens further and, in doing so, exposes a greater length of the slot 41 to the constant depression between valves 4 and 1. The increased depression (again weakened by atmospheric air admitted through restrictors 66A and 66B in valve 101A) is applied to diaphragm 47 and results in an increased closing force on valve member 112 causing a further rise in fuel pressure in supply conduits 52 and 63. During acceleration, if the throttle valve 1 is suddenly opened the depression between the valves 4 and 1 rises suddenly. The increase is effective immediately, through diaphragm 47 and valve member 112 to raise the fuel pressure in supply conduits 52 and 63.

It will be appreciated that the use of the pressurizing mechanism 100 shown in FIG. 1 is not restricted to systems in which fuel metering is also controlled by the maintenance of a constant depression in the air intake 3 (e.g., by the mechanism 102). Similarly, use of the signal valve mechanism 102 is not restricted to those systems in which fuel pressure is also controlled in dependence on the maintenance of a constant depression in the air intake (e.g., by the mechanism 100).

It has been stated above that the valve 101A shown in FIG. 1 is operable to provide an enriched fuel/air ratio when the engine is cold. The operation of the valve 101A will now be described.

When valve 101A is open, atmospheric air is admitted, as described above, to conduit 43 via restrictors 66A and 66B in the valve. The restrictor 66A can be closed manually to restrict the flow of atmospheric air into conduit 43 and thereby increase the effective depression applied to diaphragm 47 and raise fuel pressure in the supply conduits 52 and 63. The result is that the engine receives a richer fuel/air mixture. The restrictor 66B which remains open under all operating conditions is adjustable to vary the setting of valve 101A.

It will be appreciated that, although valve 101A has been described as having utility under engine starting conditions it is not restricted to use under these conditions and could, being a manually operated valve, be used whenever a richer fuel/air mixture is required. It will also be appreciated that the valve 101A is not essential to the functioning of the metering control mechanism 102 or (except in so far as it provides a restriction 66A, 66B through which atmospheric air is admitted to conduit 43) to the functioning of the pressurizing mechanism 100: the valve 101A could, accordingly, be omitted. In order to ensure that the fuel in the system remains liquid at all times even when the fuel temperature rises considerably above normal ambient temperatures it is desirable to maintain it at a pressure higher than atmospheric. It is for this reason that the relief valve 57 is introduced. It should be noted that, since chamber 53 of pressurizing mechanism 100 is connected to chamber 54 of the mechanism, the pressure raised by relief valve 57 has no effect on the operation of the control mechanism.

The excess fuel return conduit 56 from the pressurizing mechanism 100 to the relief valve 57 also communicates with a conduit 62 which leads to a chamber 74 on one side of a diaphragm 77 in the distributor unit 75. Fuel from the metering unit 80 is supplied via the conduit 80A to a chamber 79 on the other side of the diaphragm 77 and a spring 76 in chamber 74 urges the diaphragm towards a seat 78 to cutoff communication between the chamber 79 and the injector devices 83. The pressure in chamber 74 is a constant being equal to the pressure raised by relief valve 57 plus a constant pressure due to the spring 76. Thus the fuel flow to the engine (which is through chamber 79) is unaffected by the pressure imposed on the fuel in conduit **63** by the relief valve **57**. The distributor unit **75**, as mentioned above, leads fuel to the injector nozzles **83** which introduce the fuel into the engine mixture induction system. After passing across the valve seat **78**, the fuel is at low pressure, particularly under engine idling and low power conditions. In view of this, and to avoid fuel vapourization all conduits downstream of the distributor unit **75** are of small cross section.

The above arrangement is disadvantageous in that it provides an enriched fuel/air mixture for the engine during sudden acceleration, as may be seen from the following example:

Suppose that the normal depression between valves **1** and **4** in conduit **3** is 1* Hg; that the resultant fuel pressure that is, the pressure in excess of that raised by relief valve **57** in supply conduit **63** is 10 p.s.i., that the substantially constant minimum pressure raised by relief valve **57** is 15 p.s.i. and that the spring **76** imposes a substantially constant load equivalent to 2 p.s.i. The absolute fuel pressure in conduit **63** is then 25 p.s.i. and under steady conditions the fuel metering pressure is 25–(15+2)=8 p.s.i.

On sudden acceleration, before the position of the air valve **4** has been adjusted, the depression between valves **1** and **4** may rise momentarily to 2" Hg. This in turn raises resultant the fuel pressure in conduits 63 to 20 p.s.i. so that the absolute pressure becomes 35 p.s.i. The metering pressure is now 35– 15+2)=18 p.s.i. Thus, while the depression has changed in the ratio 2/1 the fuel metering pressure has changed in the ratio 2.25/1, providing enrichment during acceleration. When the air valve **4** has opened to restore the 1" Hg depression between valves **1** and **4**, the fuel metering pressure reverts to its original value but the new position of the air valve **4** is accompanied by readjustment of the metering valve **80**.

The spring in the fuel distributor also performs the secondary, but important, function of preventing fuel from being delivered to the injectors when the engine is not turning.

The conduit **130** which is shown in dotted lines in FIG. **1** and which, in the above description, was assumed to be absent connects the air intake conduit **3** on the atmospheric side of the valves **1** and **4** to the chamber **94** in the signal valve mechanism **102** and also to the chamber **131** in the pressurizing mechanism **100** and the atmospheric air inlet of the enrichment valve **101A**. The purpose of this conduit **130** is to nullify any effect on the depression between valves **1** and **4** of the flow resistance of the air cleaner normally included in the inlet of air intake conduit **3**. This flow resistance could have a particularly noticeable effect under high engine power conditions: the conduit **130**, is however, not essential and, as described above, chambers **131** and **94** and the inlet of valve **101A** could be left open to atmosphere.

The construction of the control mechanisms **100** and **102** of the system shown in FIG. **1** will be described in greater detail. The construction of the mechanism is similar and only the pressurizing mechanism **100** will be considered (see FIG. **3**). As already stated, the control lever **110** which transmits movement of the diaphragm **47** to the valve member **112** extends through and is capable of rocking movement within a seal **111**. This seal takes the form of an O-ring located partly in a groove in the lever **110** and partly in a groove in the housing of the mechanism and, it will be noted, serves the purpose of sealing chamber **45** which is exposed to the control depression produced between valves **1** and **4** from chamber **53** which, in operation of the system, contains fuel under pressure. This particular construction permits rocking movement of the lever **110** but prevents axial movement and minimises friction and wear. The need for sliding or rotating seals between depression zones and pressurized fuel zones is also overcome. It will be appreciated that the use of valve control mechanism of this particular construction is not restricted to fuel injection systems. Similar mechanisms could be employed in other circumstances when it is desired to control the flow of a pressurized fluid in dependence upon a control vacuum. The arrangement shown in FIG. **3**, for example, could be used to control the flow of any fluid between the ports **53A** and **53B** in chamber **54** in dependence upon any suitable control fluid pressure differential applied across the diaphragm **47**.

The metering valve **80** of the system shown in FIG. **1** be of the type described in U.S. Pat. No. 3,342,449 including a tubular member having a V-slot registrable with an aperture in a sleeve in which the tubular member is located. Alternatively the V-slot may be formed in the sleeve and registrable with an aperture in the tubular member. The tubular member, which may be closed at one end, can be connected to supply fluid to be metered to the orifice or to receive metered fluid from the orifice. Alternatively, the metering valve may be of the type shown in FIGS. **4** and **5** of the accompanying drawings.

The metering valve shown in FIGS. **4** and **5** includes a pin-shaped valve member **182** located within a tubular sleeve **183**. The valve member **182** is engaged at one end by a lever **184** which is rotatable with a spindle **185**, and a further lever **186** which is also secured to the spindle **185** carries a roller **187** which cooperates with a cam **188** mounted on a spindle **189**. The valve member **182** urged towards engagement with the lever **184** by a spring **190**. At the other end of the valve member **182**, a tapered slot **194** is formed which may have V-shaped section as shown in FIG. **6**, and the bore **191** of the tubular sleeve **183** surrounding this end of the valve member is enlarged. An aperture **192** is formed in the tubular sleeve **183** to define a projection **193** between the aperture **192** and the enlarged bore portion **191**. The projection **193** cooperates with the tapered slot **194** in the valve member **182** to define a metering orifice the area of which varies according to the axial position of the valve member **182** relative to the sleeve **183**. Suitable means (not shown) are provided to ensure that the valve member **182** cannot rotate relative to the sleeve **183**.

When the metering valve shown in FIGS. **4** and **5** is employed in a system of the type shown in FIG. **1**, the cam spindle **189** is coupled to the lever **7** of the control mechanism in such a manner that a change in the position of the air valve **4** is accompanied by rotation of the cam spindle **189** and hence by axial movement of the metering valve member **182**. The metering orifice defined by the tapered slot **194** in the valve member **182**, and the projection **193** in the sleeve **183** is connected between the fuel supply lines **63**, **80A** (see FIG. **1**) so that fuel flow to the injector devices **83** is adjusted as the position of the air valve **4** varies.

It will be appreciated, however, that use of the metering valve shown in FIGS. **4** and **5** is not restricted to fuel injection systems of the type shown in FIG. **1**, or even to fuel injection systems in general.

One suitable arrangement by which the metering valve **80** and the piston **8A** of the system shown in FIG. **1** can be coupled to the control lever **7** is illustrated in FIG. **6**. This arrangement is shown as applied to a metering valve **80** of the type described in U.S. Pat. No. 3,342,449 but could readily be modified for application to, for example, a metering valve of the type shown in FIGS. **4** and **5**. In the arrangement shown in FIG. **6**, the piston **8A** carries a rack **121** which engages a pinion **122** mounted on a shaft **123**. The shaft **123** also carries a cam **124** which bears upon a roller **125** coupled through an arm **126** to the valve member **120** of the metering valve **80**. The valve member **120** is a tubular member in which is defined a V-slot registrable with an aperture in a surrounding sleeve (not shown) to define a metering orifice the area of which can be varied by relative rotation between the valve member **120** and the surrounding sleeve. Also mounted on the shaft **123**, but outside the metering valve unit **80** is a lever **127** coupled to the control lever **7**. Movement of the piston **8A** causes rotation of the shaft **123** and hence adjustment of the air valve **4** through the levers **127** and **7**, and also rotation of the valve member **120** trough the cam **124** and roller **125**. No precision is required in the rack and pinion arrangement **121**, **122** since it is loaded in one direction by the spring **30** of the air valve **4** and, in the particular arrangement illustrated there is no need for a close fit between the piston **8A** and its cylinder **8B** since, as shown in FIG. **1**, any fuel leakage across the piston will be returned to the fuel tank via conduit **97**.

The injector nozzles **83** of the system shown in FIG. **1**, which are not shown in detail in the drawings, may be of a conventional open, air-bled type in which air is drawn into the nozzle through suitable apertures to effect atomization of fuel passing through the nozzle. Preferably, each nozzle includes a flow equalizing restrictor, for example a small diameter stainless steel tube through which the fuel passes, the purpose of these restrictors being to ensure equal fuel distribution between the nozzles.

The system shown in FIG. **1** is a continuous injection system. Continuous injection of fuel is, however, not an essential feature of systems in accordance with the invention: for example, a system incorporating a pressurizing mechanism of the type shown at **100** in FIG. **1** could employ intermittent fuel injection in the manner disclosed in my copending U.S. Pat. application No. 46,201 filed June 25, 1970.

Modifications of the systems described above are illustrated in FIGS. **7** to **11**. In the modification shown in FIG. **7**, the fuel metering valve **80** includes two variable fuel metering orifices **196, 197** rather than only one metering orifices as in the metering valves described above. The valve also includes a fixed restrictor **195** through which fuel is fed from the fuel supply conduit **63** to the metering orifices **196, 197**. The orifice **196** controls the passage of fuel from the conduit **63** to the conduit **80A** and hence to the distributor unit **75** and injector nozzles **83**, and the orifice **197** connects the supply conduit **63** to the conduit **62** which contains fuel at the substantially constant pressure determined by the relief valve **57**. Both variable orifices **196, 197** are coupled to the control lever **7** of the air valve **4**, the arrangement being such that as the air valve opens, so the orifice **196** is enlarged while the orifice **197** is reduced. The remainder of the system may be as shown in FIG. **1**.

In the modification shown in FIG. **8**, the metering valve **80** includes a fixed restrictor **195** and a variable orifice **197** as in the arrangement shown in FIG. **7**, but the variable orifice **196** of FIG. **7** is replaced by a fixed orifice **199**. The variable orifice **197** is coupled to the control lever **7** of the air valve **4** so that, as the air valve opens, the orifice **197** is reduced and less fuel is bypassed to the conduit **62** with the result that more fuel passes through the fixed orifice **199** to the distributor unit **75** and injector nozzles **83**.

The modification shown in FIG. **9** illustrates the use of the system shown in FIG. **1** in conjunction with a dual induction manifold arrangement of the type including a plurality of intake tubes connected to the engine inlet ports and a plurality of injector nozzles for introducing fuel into the intake tubes, a further intake tube which is also connected to the engine inlet ports and an injection nozzle for introducing fuel into the further intake tube.

In the modification shown in FIG. **9**, metered fuel from the conduit **80A** (which corresponds to the conduit **80 A** in FIG. **1**) is fed through conduit **100** to the chamber **79** of the distributor unit **75** from which, as in FIG. **1**, fuel may pass to a set of injector devices (not shown) via a conduit **81**. In this modification, fuel from conduit **80A** is also fed through conduit **101** to a chamber **133** of a second similar distributor unit **103** from which fuel may pass, to a further injector device or set of injector devices (not shown) via a conduit **116**. Fuel at the pressure in conduit **63** (see FIG. **1**) is applied to chamber **74** of distributor unit **75** via conduits **104, 106** and restrictor **106** and is also applied to the corresponding chamber **115** of the second distributor unit **103** via conduits **104, 134** and restrictor **109**. The conduits **106, 134** are connected to solenoid valves **108** and **132** respectively and the solenoid valves which are closed when not energized are connected, via a conduit **135** to the conduit **62** which contains fuel at the substantially constant pressure determined by the relief valve **57** (see FIG. **1**).

When the valves **108, 132** are closed, the pressures on both sides of the diaphragms in the distributor units **75, 103** are equal, so that the diaphragms remain seated and no fuel passes to the engine via conduits **81** and **116**. Suitable control means (not shown) cause energization of the solenoid valves **108, 132**, independently, in dependence on a suitable engine operating parameter for example the position of the throttle valve **1** (see FIG. **1**) or the vacuum in the air intake conduit **3** downstream of the throttle valve. When the solenoid valve **108** is energized, the pressure in chamber **74** of distributor unit **75** drops to the constant pressure in conduit **62**. This constant pressure is lower than the pressure in conduit **80A** so that the diaphragm of distributor unit **75** lifts and fuel is fed to the engine via conduit **81**. Similarly, when the solenoid valve **132** is energized, fuel is fed to the engine via conduit **81**.

The modification shown in FIGS. **10** and **11** relate to the slot arrangement **41** shown in FIG. **1**, through which the control depression between valves **1** and **4** in the air intake conduit **3** is applied, to a variable extent to the fuel pressurizing device **100**. In the arrangement shown in FIG. **10**, the reference numerals **1, 3, 4** and **7** indicate (as in FIG. **1**) the throttle valve, the air intake conduit, the air valve and the air valve control lever respectively. The slot **41** shown in FIG. **1** is, however, omitted and the conduit **43** which leads to the fuel pressurizing device **100** (not shown) communicates with the air intake conduit **3** at a point between the valves **1** and **4**.

The conduit **43** is vented to atmosphere through a fixed restrictor **200**, and a variable restrictor **201** formed by a cam plate **202** cooperating with a vent **203** in the conduit. The cam plate **202** is coupled to the linkage **7** and is moveable by the linkage to vary the restrictor **201**.

The pressure communicated to the fuel pressurizing device **100** through conduit **43** (and hence the pressure to which the engine fuel supply is raised) is determined by the of communication between the conduit **43** and atmosphere through the restrictor **201**. Adjustment of the restrictor **201** accompanies adjustment of the position of the air valve **4** and this, in turn, depends on engine air intake. The fuel supply is thus pressurized in dependence on engine air intake.

In the alternative arrangement shown in FIG. **11**, the variable restrictor **201** is formed by a needle valve, movement of the needle valve member **205** to vary the restrictor **201** being controlled by a cam **206** coupled to the linkage **7**. This arrangement functions in a similar manner to that shown in FIG. **10**.

I claim:

1. A fuel injection system for an internal combustion engine, including a fuel flow path, means operable to supply pressurized fuel to the flow path, at least one fuel injector device connected to receive fuel from the flow path, and a fuel metering device connected in the flow path and operable to vary fuel flow to the injector device(s), an air valve located in the engine air supply path to produce a control pressure differential over a portion of the air supply path, a fuel pressure control circuit which is connected to receive fuel from the flow path, fuel pressure-responsive means exposed to pressure in the said control circuit and connected to the air valve to adjust the air valve in response to variation in the fuel pressure in the control circuit, and a signal valve mechanism including valve means connected in the control circuit, the signal valve mechanism being exposed to the control pressure differential for operation in response to a variation in the control pressure differential from a predetermined value to operate said valve means to produce a magnified variation in the fuel pressure in the control circuit and thereby adjust the air valve to maintain the pressure differential at the said predetermined value, the fuel metering device being coupled to the air valve for adjustment in response to adjustment of the air valve whereby fuel flow to the injector device(s) is varied in response to adjustment of the air valve.

2. A system as claimed in claim **1**, including a fuel pressurizing device connected in the flow path and operable in response to adjustment of the air valve to vary the pressure at which fuel flows to the injector device(s).

3. A system as claimed in claim **1** in which the air valve is located in the engine air supply path upstream of the throttle valve to produce the control pressure differential between the air valve and the throttle valve.

4. A system as claimed in claim 1 in which the said fuel pressure-responsive means is exposed to the pressure in a control chamber which is connected to the said control circuit, the control circuit being connected to receive fuel at constant pressure from the fuel flow path and the said valve means being connected in the control circuit downstream of the connection to the control chamber.

5. A system as claimed in claim 4, in which the signal valve mechanism includes a valve chamber and a pressure chamber, the valve chamber being connected in the said control circuit and having an inlet including said valve means, and the pressure chamber being exposed to the control pressure differential and including a pressure-responsive element operably coupled to the said valve means by a pivotally movable linking member, the said valve chamber and pressure chamber being sealed from each other by the pivotal mounting of the linking member.

6. A system as claimed in claim 5, in which the pivotal mounting is an O-ring through which the linking member extends.

7. A system as claimed in claim 6, in which the O-ring is located in a groove in the linking member to prevent movement of the linking member into and out of the pressure chamber and the valve chamber.

8. A system as claimed in claim 1, including at least two fuel injector devices each connected to receive fuel from the fuel flow path, and having respective fuel pressure responsive injector control valves each exposed to fuel pressure in the flow path and operable to permit fuel flow to the associated injector device, and respective control devices operable independently of each other in response to an engine operating parameter to adjust the associated injector control valve from an inoperative state in which a predetermined fuel pressure in the flow path is insufficient to operate the injector control valve, to an operative state in which the said predetermined fuel pressure in the flow path is sufficient to operate the injector control valve.

9. A system as claimed in claim 1, in which the fuel metering device includes a variable metering orifice which is connected in the fuel flow path to supply fuel to the injector device(s) and the area of which is adjustable in response to adjustment of the air valve.

10. A system as claimed in claim 1, in which the fuel metering device includes a variable metering orifice which is connected in the fuel flow path to bypass fuel from the injector device(s) and the area of which is adjustable in response to adjustment of the air valve.

11. A system as claimed in claim 1, in which the fuel metering device includes an elongated valve member located within and axially movable relative to a sleeve member, one of the said members including a groove which extends in the axial direction and the cross-sectional area of which varies in that direction, the groove cooperating with a portion of the other of the said members to define a metering orifice the area of which is variable by relative axial movement between the valve member and the sleeve member.

12. A system as claimed in claim 11, in which the groove has a V-shaped cross section, the depth of the groove varying in the axial direction.

13. A system as claimed in claim 1, which is operable to discharge fuel continuously from the injector device(s).

14. A fuel injection system for an internal combustion engine, including a fuel flow path, at least one fuel injector device connected to receive fuel from the flow path, and a fuel pressurizing device connected to supply pressurized fuel to the flow path and operable to vary the pressure at which fuel flows to the injector device(s), an air valve located in the engine air supply path to produce a control pressure differential over a portion of the air supply path, a fuel pressure control circuit which is connected to receive fuel from the flow path, fuel pressure-responsive means exposed to pressure in the said control circuit and connected to the air valve to adjust the air valve in response to variation in the fuel pressure in the control circuit, and a signal valve mechanism including valve means connected in the control circuit, the signal valve mechanism being exposed to the control pressure differential for operation in response to a variation in the control pressure differential from a predetermined value to operate said valve means to produce a magnified variation in the fuel pressure in the control circuit and thereby adjust the air valve to maintain the pressure differential at the said predetermined value, the fuel pressurizing device being coupled to the air valve for operation in response to adjustment of the air valve whereby the pressure at which fuel flows to the injector device(s) is varied in response to adjustment of the air valve.

15. A system as claimed in claim 14, in which the fuel pressurizing device is a pressure-responsive device exposed to the control pressure differential to an extent which varies with adjustment of the air valve.

16. A system as claimed in claim 15, including means operable to supply fuel to the fuel flow path in excess of the engine operating requirements, the pressurizing device being operable to bypass fuel from the flow path in dependence on the adjustment of the air valve.

17. A system as claimed in claim 14, in which the air valve is located in the engine air supply path upstream of the throttle valve to produce the control pressure differential between the air valve and the throttle valve.

18. A system as claimed in claim 14, in which the said fuel pressure-responsive means is exposed to the pressure in a control chamber which is connected to the said control circuit, the control circuit being connected to receive fuel at constant pressure from the fuel flow path and the said valve means being connected in the control circuit downstream of the connection to the control chamber.

19. A system as claimed in claim 15, in which the fuel pressurizing device communicates through a conduit with a slot which extends along the engine air supply path in the region of the control pressure differential and adjacent the air valve whereby the length of the slot exposed to the control pressure differential is dependent on the adjustment of the air valve.

20. A system as claimed in claim 15, in which the fuel pressurizing device communicates with the control pressure differential region of the engine air supply path through a conduit which is vented to atmosphere through a variable restrictor which is adjustable by operation of the signal valve mechanism.

21. A system as claimed in claim 16, including means operable to maintain a substantially constant pressure in the fuel bypass path of the pressurizing device, which substantially constant pressure is sufficient to prevent fuel vapourisation.

22. A system as claimed in claim 21, in which the fuel flow path is connected to the injector device(s) through a distributor unit including a pressure-responsive member biased, by a resilient member and fuel at the said substantially constant pressure, to a closed position to prevent fuel flow to the injector device(s) and movable against the bias to an open position by fuel pressure in the fuel flow path.

23. A system as claimed in claim 19, including a fuel pressure adjustment mechanism operable to admit atmospheric air to the conduit connecting the fuel pressurizing device to the control pressure differential region to operate the pressurizing device independently of the air valve.

24. A system as claimed in claim 16, in which the fuel pressurizing device includes a valve chamber and a control pressure chamber, the valve chamber communicating with the fuel flow path under control of a fuel flow control valve member, and the control pressure chamber being exposed to the control pressure differential to an extent which varies with adjustment of the air valve, the control pressure chamber including pressure-responsive element operably coupled to the fuel flow control valve member by a pivotally movable linking member, the valve chamber and the control pressure chamber being sealed from each other by the pivotal mounting of the linking member.

25. A system as claimed in claim 18, in which the signal valve mechanism includes a valve chamber and a pressure

chamber, the valve chamber being connected in the said control circuit and having an inlet including said valve means, and the pressure chamber being exposed to the control pressure differential and including a pressure-responsive element operably coupled to the said valve means by a pivotally movable linking member, the said valve chamber and pressure chamber being sealed from each other by the pivotal mounting of the linking member.

26. A system as claimed in claim **14**, including at least two fuel injector devices each connected to receive fuel from the fuel flow path, and having respective fuel pressure responsive injector control valves each exposed to fuel pressure in the flow path and operable to permit fuel flow to the associated injector device, and respective control devices operable independently of each other in response to an engine operating parameter to adjust the associated injector control valve from an inoperative state in which a predetermined fuel pressure in the flow path is insufficient to operate the injector control valve, to an operative state in which the said predetermined fuel pressure in the flow path is sufficient to operate the injector control valve.

27. A system as claimed in claim **14**, which is operable to discharge fuel continuously from the injector device(s).

28. A system as claimed in claim **14**, which is operable to discharge fuel intermittently from the injector device(s).

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