July 11, 1967 H. E. JACKSON 3,330,541

FUEL INJECTOR DEVICES AND SYSTEMS

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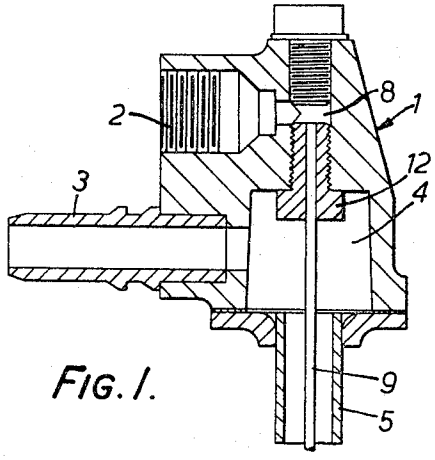


FIG. 1.

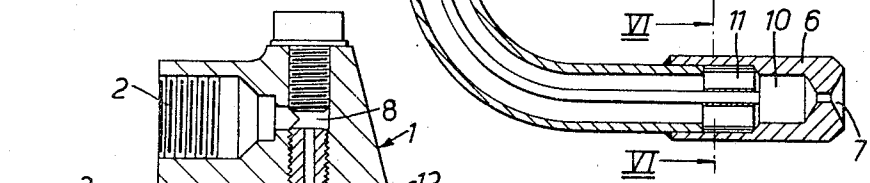
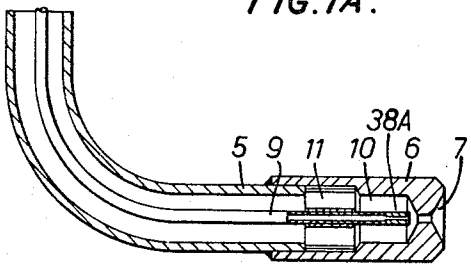


FIG. 1A.



July 11, 1967 H. E. JACKSON 3,330,541

FUEL INJECTOR DEVICES AND SYSTEMS

Filed Feb. 23, 1965 5 Sheets-Sheet 2

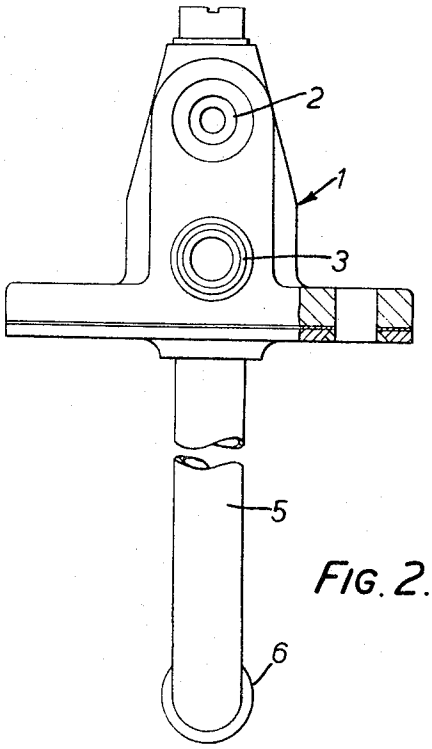


FIG. 2.

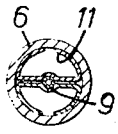


FIG. 3.

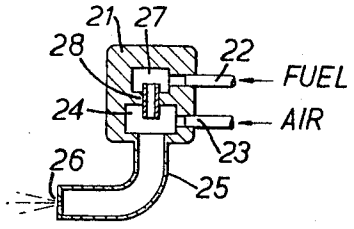


FIG. 4.

July 11, 1967 H. E. JACKSON 3,330,541

FUEL INJECTOR DEVICES AND SYSTEMS

Filed Feb. 23, 1965 5 Sheets-Sheet 3

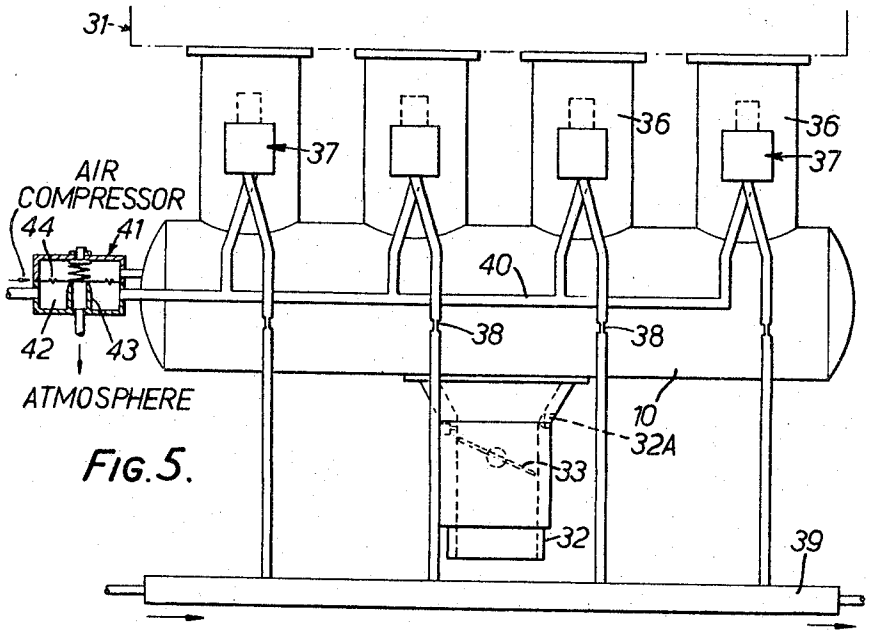


FIG. 5.

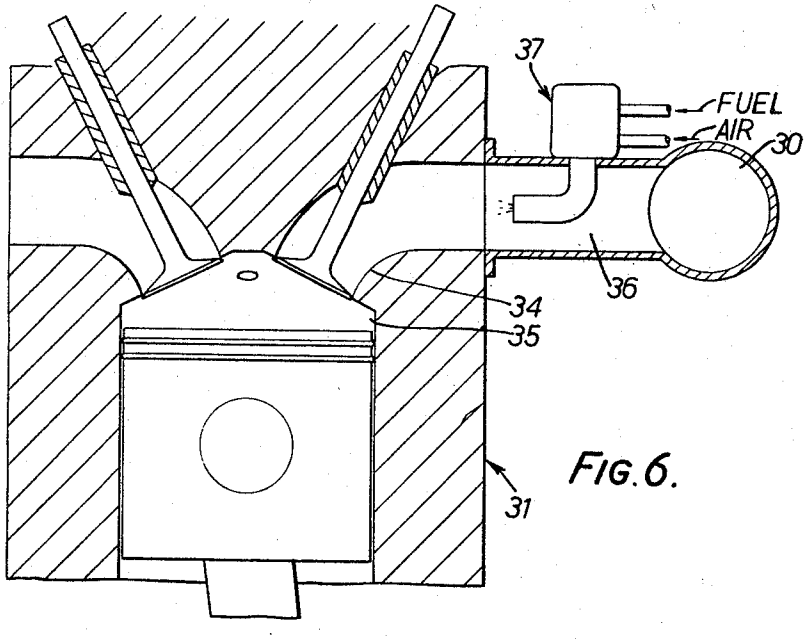


FIG. 6.

July 11, 1967 H. E. JACKSON 3,330,541

FUEL INJECTOR DEVICES AND SYSTEMS

Filed Feb. 23, 1965 5 Sheets-Sheet 4

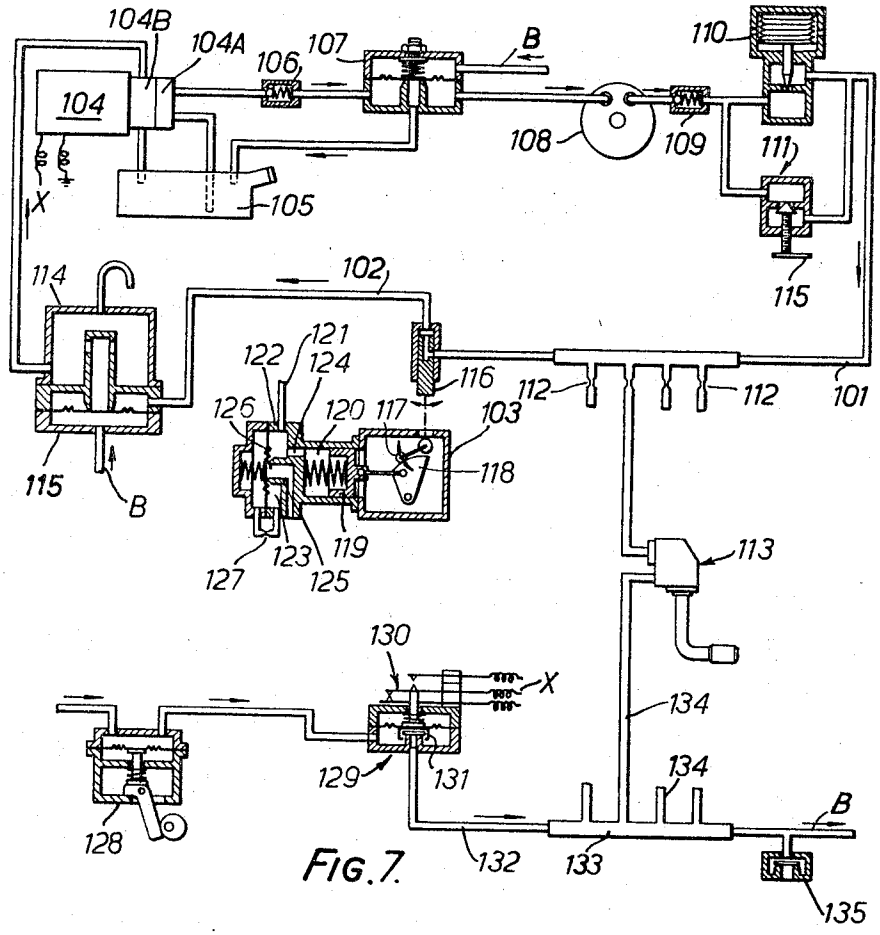


FIG. 7.

July 11, 1967 H. E. JACKSON 3,330,541

FUEL INJECTOR DEVICES AND SYSTEMS

Filed Feb. 23, 1965 5 Sheets-Sheet 5

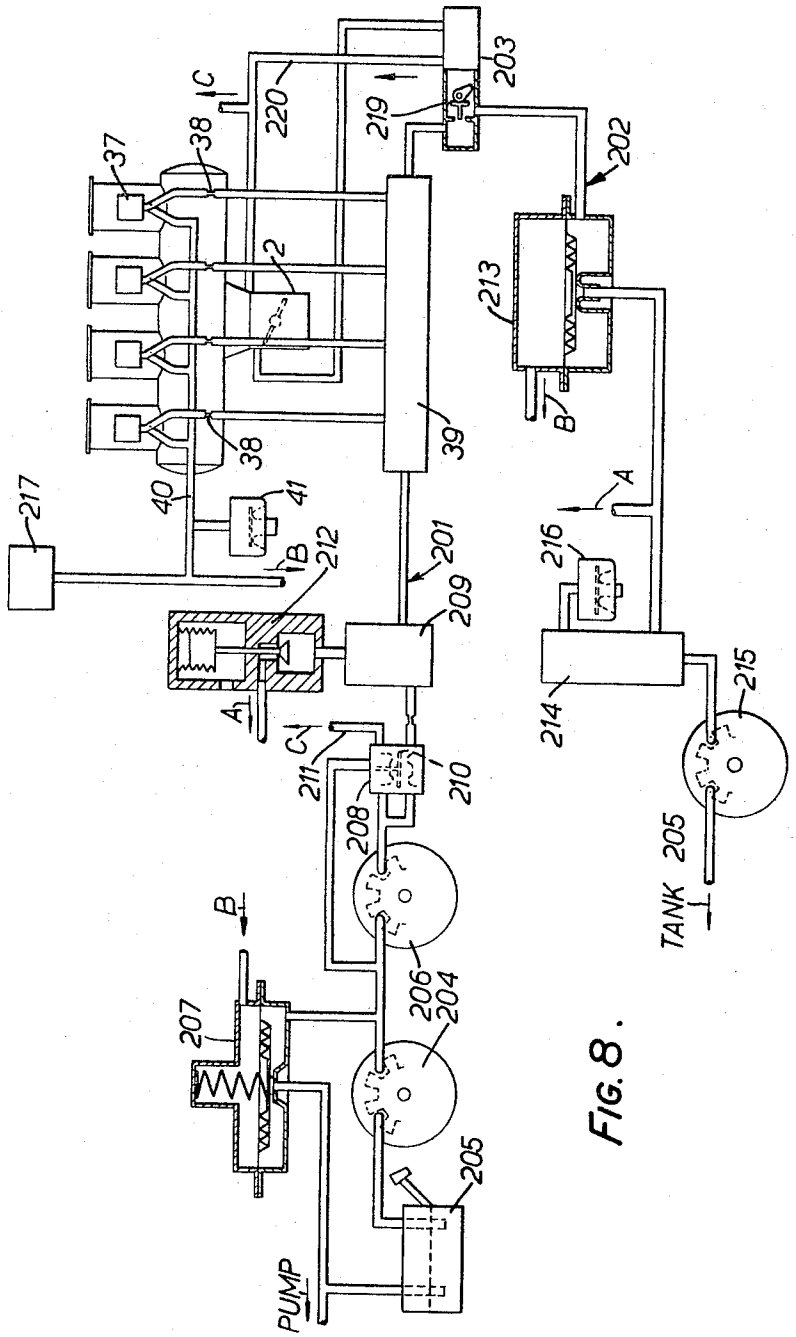


FIG. 8.

United States Patent Office 3,330,541 Patented July 11, 1967

3,330,541

FUEL INJECTOR DEVICES AND SYSTEMS

Harold E. Jackson, Devon, England, assignor to Petrol Injection Limited, Plympton, England, a British company

Filed Feb. 23, 1965, Ser. No. 434,417
Claims priority, application Great Britain, Feb. 25, 1964, 7,896/64; June 24, 1964, 26,173/64
4 Claims. (Cl. 261—23)

This invention relates to open fuel injection devices and to fuel injection systems incorporating such devices. Such injector devices incorporate open injector nozzles, i.e. nozzles which do not incorporate flow control valve devices.

The invention relates particularly to fuel injector devices suitable for use in low pressure continuous fuel injection systems in which metered fuel is fed to the devices and atomized therein by low-pressure atomizing air prior to discharge from the injector device at substantially the pressure of the atomizing air. Examples of such systems are disclosed in my co-pending application Ser. No. 482,994 filed Aug. 10, 1965, now U.S. Patent No. 3,285,233, for "Fuel Injection Systems" (a continuation of my earlier applications Ser. Nos. 330,874 filed Dec. 16, 1963, and 434,362 filed Feb. 23, 1965, both now abandoned). Typically, fuel is supplied to the injector devices at pressures up to several tens of p.s.i. and atomizing air at pressures of a few p.s.i

It is an object of this invention to provide a fuel injection device suitable for such use, which can be relatively simply constructed and is amenable to economic production.

It is also an object of the invention to provide in a low pressure, continuous fuel injection system for an internal combustion engine, in which the injector devices have open outlet orifices disposed in the engine air intake manifold so that the interiors of the injector devices are subject to depressed pressure conditions in the manifold, vacuum relief valve means operable to prevent subatmospheric pressure conditions arising within the injector devices, so to ensure correct supply of fuel by the injector devices under all pressure conditions with the manifold structure during operation of the engine.

In one embodiment, the body portion has superposed transverse fuel and air inlets and the injector nozzle is dependent from the floor of the air chamber. The nozzle can be straight or bent as desired. The fuel tube extends through the air chamber into the injector nozzle, terminating short of the outlet orifice so that air passing through the nozzle impinges on the fuel stream emergent from the fuel tube, breaks it into globules and discharges the atomized fuel through the outlet orifice. In this arrangement the fuel tube can incorporate a flow restrictor device, located adjacent the outlet of the fuel tube.

By way of example, the invention will be described in greater detail with reference to the accompanying drawings, in which:

FIG. 1 is a sectional elevation of a preferred form of injector device according to the invention,

FIG. 1A is a view, similar to FIG. 1, of a modified construction thereof,

FIG. 2 is an end view, partly sectional, of the device shown in FIG. 1,

FIG. 3 is a section on the line III—III in FIG. 1,

FIG. 4 is a schematic section of an alternative construction of an injector device according to the invention,

FIGS. 5 and 6 are plan and elevational section views illustrating the disposition of injector devices according to the invention in an internal combustion engine, and

FIGS. 7 and 8 are schematic illustrations of fuel injection systems incorporating injector devices according to the invention.

FIGS. 1, 2 and 3 show a preferred construction of an injector device according to the invention. The injector device has a body portion **1** having superposed transverse fuel and atomizing air inlets **2** and **3** respectively. The air inlet **3** communicates with a chamber **4** in the lower portion of the body **1** which, in turn, communicates with an open injector nozzle tube **5** dependent from the base of the body portion. The outlet end of the nozzle tube **5** terminates in a nozzle cap **6** having a flared outlet orifice **7**. The outlet end of the nozzle tube **5** is bent through 90° with respect to its inlet end. The fuel inlet **2** communicates with a fuel chamber **8** from which extends a fuel tube **9** passing through the air chamber **4** into the nozzle tube **5**, terminating short of the outlet orifice **7** to define a mixing chamber **10** in the nozzle cap **6**. The fuel tube **9** is centered in the nozzle tube **5** by a pair of detachable spring clips **11** located at the outlet end of the nozzle tube and at its inlet end is secured in the body portion **1** by a threaded coupling **12**. The clips **11** are so shaped that they offer little resistance to air flow through the nozzle tube **5**.

In use of the injector device described above, metered liquid fuel is fed to the inlet **2** at a low pressure, typically several tens of p.s.i. and passes from the chamber **8** into the fuel tube **9** from which it emerges into the mixing chamber **10**. Low pressure air is fed to the inlet **3**, typically at a pressure of a few p.s.i., and passes from the air chamber **4** into the nozzle tube **5** and in the mixing chamber **10** impinges on and entrains fuel emergent from the fuel tube **9**, breaking the fuel stream into globules and discharging the atomized fuel through the outlet orifice **7** at a pressure substantially that of the atomizing air. Passage of the fuel through the outlet orifice increases the atomization thereof. As mentioned above, the clips **11** offer little resistance to air flow and do not impair effective atomization of the fuel.

The injector device shown in FIGS. 1–3 can be modified as illustrated by FIG. 1A. The modification consists in the extension of the fuel tube **9** to a point closely adjacent the outlet orifice and the inclusion in the extension of a flow restrictor **38A**. The outlet end of the fuel tube **9** is located so closely adjacent the outlet orifice **7** that diffusion of the emergent fuel stream jet is precluded, the jet being directed into the outlet orifice. Apart from this feature, the injector device is identical to that shown in FIGS. 1–3.

An alternative construction of a fuel injector device in accordance with the invention is shown, diagrammatically, in FIG. 4. The device has a body portion **21** having superposed transverse fuel and atomizing air inlets **22** and **23** respectively. The air inlet **23** leads to a chamber **24** which communicates with an open injector nozzle tube **25** dependent from the base of the body portion **21**. The nozzle tube **25** has an outlet orifice **26** and its outlet end is bent through 90° with respect to its inlet end. The fuel inlet **22** leads to a chamber **27** which communicates with the air chamber **24** via a tube **28** which preferably, as shown, is aligned with the inlet end of the injector nozzle tube **25** so that fuel emergent from the tube **28** is directed into the nozzle tube.

In use of this injector device, metered liquid fuel and atomizing air are fed to the inlets **22** and **23** at similar pressures to those disclosed in relation to FIGS. 1–3. The fuel passes from the inlet **1** into the chamber **27** and thence via the tube **28** to the chamber **24**. Air fed to the inlet **3** passes through the chamber **24** into the nozzle tube **25**, the speed of entry of air into the nozzle tube being sufficient to break up the fuel stream emergent from the

tube **28** into small globules. The entrained globules pass along the nozzle tube **25** and are discharged through the outlet orifice **26** which serves to increase the atomization of the fuel. The atomized fuel is discharged substantially at the atomizing air pressure.

The injector devices described above are suitable for incorporation in a low pressure, continuous fuel injection system for an internal combustion engine. The manner of disposition of the injector devices, together with details of part of the atomizing air supply system are illustrated in FIGS. 5 and 6.

FIGS. 5 and 6 show the air inlet manifold **30** of an internal combustion engine having a cylinder block **31** which in FIG. 5 is indicated in broken outline. The manifold **30** has an air intake conduit **32** in which is disposed the throttle butterfly valve **33**; the manifold is connected to the inlet passages **34** of the respective engine cylinders **35**, one of which is shown in FIG. 6, by branch conduits **36** best shown in FIG. 5. The air intake conduit **32** also has a port **32A** located on the engine side of the throttle valve **33** in all positions of the latter. The injector devices **37** are disposed one in each conduit **36**, the injector nozzles extending through the walls of the conduits **36** with their outlet orifices directed towards the respective inlet passages **34**. The injector devices **37** are indicated in block outline and can be constructed either as shown in FIGS. 1–3 or as shown in FIG. 4.

The fuel inlets of the injector devices **37** are connected via flow equalizing restrictors **38** to a fuel supply line **39** supplied from a fuel source in a manner to be described hereinafter. If injector devices of the type shown in FIG. 1A are used, then the flow restrictors **38** are not used, their function being fulfilled by the restrictors **13** forming part of the injector devices.

The air inlets of the injector devices **37** are connected to a common air supply line **40** supplied from an air compressor, for example a diaphragm pump. The air line **40** incorporates a vacuum relief valve **41** having a lower chamber **42**, forming part of the air supply line **40**, containing an annular seat **43** open at one end to atmospheric pressure and having its opposite end normally closed by a resilient diaphragm **44**. The valve **41** has an upper chamber connected to the manifold **30** so that the upper side of the diaphragm **44** is exposed to the manifold pressure. The vacuum relief valve **41** ensures that depressed pressure conditions in the inlet manifold **30**, to which the open injector devices **37** are exposed, does not affect fuel flow through the injector devices.

As described with reference to FIGS. 1–3 and FIG. 4 the injector devices **37** receive fuel and air at low pressures and the fuel/air mixture is ejected into the intake passages **34** at substantially the pressure of the atomizing air supply, i.e. a few p.s.i.

The construction of the injector devices is simple yet results in efficient atomization and injection of fuel without relying on the use of mechanical devices for atomization.

FIGS. 7 and 8 illustrate fuel injection systems incorporating injector devices according to the invention, which are located in the manner illustrated in FIGS. 5 and 6.

The fuel circuit of the system shown in FIG. 7 comprises a ring main having a supply branch **101** and a return branch **102**, flow to the latter being controlled by a metering valve **103** operable in response to engine inlet manifold pressure. A priming pump **104A** driven by an electric motor **104** supplies fuel from a tank **105** to a fuel line via a check valve **106** which prevents drainage of the fuel supply ring main during engine shutdown. From the check valve **106**, the fuel passes to a relief valve **107** which is set to maintain a standing fuel pressure in the supply line **101** at a convenient level, e.g. 3 p.s.i. Surplus fuel is returned to the tank **105** via the relief valve **107**. From the relief valve, fuel passes to an engine driven impeller **108** which raises the fuel pressure to a level dependent on engine speed and passes the fuel through a check valve **109**, which removes some or all of the standing pressure, to a pair of flow restrictors **110** and **111** which determine fuel flow in the branch **101**. The supply branch **101** contains a fuel manifold connected by flow equalizing restrictors **112** to the fuel inlets **2** of injectors **113** of the type shown in FIGS. 1–3. Only one such injector is shown in FIG. 7 but it will be understood that one injector device is provided for each engine cylinder, as indicated in FIG. 5.

The downstream end of the fuel manifold is connected via the metering valve **103** to the return branch **102** of the fuel ring main. Fuel from the metering valve is passed to a collection chamber **114** via an air balance valve **115** from which it is pumped back to the tank **105** by a scavenge pump **104B**, also driven by the electric motor **104**.

Of the flow restrictors **110** and **111**, the former has a resilient bellows responsive to atmospheric pressure to adjust fuel flow in accordance with atmospheric pressure. The restrictor **111** is normally closed but can be opened, either manually or automatically, by a control **115** to supplement fuel supply to the injector devices for cold starting conditions and warming up.

The metering valve **103** has a ported sleeve **116** rotatable in either sense by a follower **117** movable by a cam **118**. The cam **118** is coupled to a piston **119** movable against a spring in a cylinder **120** in response to engine inlet manifold vacuum. The vacuum pressure is connected to the cylinder **120** by a conduit **121** leading to a diaphragm divided chamber **122**, one compartment **123** of which communicates with the cylinder via a passage **124**. The compartment **123** contains an annular seating member **125**, normally closed at one end by a resilient diaphragm **126**, and having its other end exposed to atmospheric pressure. The compartment **123** communicates with the other side of the diaphragm **126** via a restriction **127** such that under steady and slowly changing pressure conditions in the compartment **123**, the diaphragm **126** remains seated. Variations in engine inlet manifold pressure cause movement of the piston **119** and corresponding rotation of the ported sleeve **116** to vary the quantity of fuel bled to the return branch **102** and hence to vary the fuel supply to the injector devices. The diaphragm chamber **122** acts as an acceleration response device, ensuring that there is minimum lag between rapid opening of the engine throttle and consequent increase in fuel supply to the injector devices. In the event of a rapid throttle opening, the engine inlet manifold pressure quickly rises but there is some delay in transmission of this change to the cylinder **120** and consequently lag in the piston **119** taking up a new equilibrium position. This is counteracted by the restrictor **127** which results in a marked pressure difference across the diaphragm **126** so that it becomes unseated exposing the cylinder **120** directly to atmospheric pressure, causing closing movement of the metering valve **103** and supplementing the fuel supply to the injector devices until pressure balance again exists across the diaphragm **126** with the piston **119** in a new equilibrium position. This sequence of operation is very rapid, normally taking place in under half a second.

The atomizing air supply to the injector devices **113** is obtained from an engine operated diaphragm pump **128**. The output from the pump **128** operates a diaphragm switch **129** which controls operation of the electric motor **104** via a contact set **130**. The contact set has three contacts, the lower two being closed in the dead engine condition. Operation of the engine starter switch applies current to the centre contact and energizes the motor **104** via the lower contact. Operation of the air pump **128** raises the diaphragm of the switch **129** so that the centre contact of the set **130** makes the upper contact, through which the motor **104** continues to be energized. As the diaphragm of the switch **129** continues to lift, the disc valve

131 of the switch 129 is unseated allowing air to pass to the air supply line 132 and via an air manifold 133 and conduits 134 to the air inlets of the injector devices 113.

For the purpose described with reference to FIGS. 5 and 6, the air line 132 incorporates a vacuum relief valve 135, indicated diagrammatically in FIG. 7 and preferably constructed and arranged as shown in FIG. 5. Thus, the lowest pressure that can arise in the air manifold 133 is atmospheric pressure, but this pressure can rise to the supply pressure of the air pump 128. This pressure is preset in the injector devices and the tendency of the pressure to oppose and reduce fuel supply to the injector devices is counteracted by the feeding of the air pump supply to the relief valve 107 and the air balance valve 115, so that fuel flow throughout the ring main circuit is opposed by the atomizing air pressure.

It will be appreciated that the injector devices 113 could, if desired, be of the type shown in FIG. 4.

FIG. 8 shows an alternative fuel injection system incorporating fuel injector devices according to the invention. In describing this system reference will be made to FIGS. 5 and 6, the former being incorporated in FIG. 8.

The system shown in FIG. 8 includes a ring main fuel supply circuit having a supply branch 201 and a return branch 202, and a fuel metering valve 203 is operable to control fuel flow from the supply to the return branch in the manner described with reference to FIG. 7.

A priming pump 204 feeds fuel from a tank 205 to an engine driven impeller 206, the output pressure from the pump 204 being maintained at a convenient standing pressure by a relief valve 207 which returns excess fuel to the tank 205. The impeller 206 is engine driven such that it raises the fuel pressure to a level dependent on engine speed. From the impeller, fuel passes via an engine starting and overrun control valve 208, an equalizing restrictor and a gas/air separator 209 to the fuel manifold 39 (see also FIG. 5).

The engine starting and overrun valve 208 comprises a valve member 210 having two seated positions in which fuel flow through the valve is shut-off. The position of the valve member 210 is controlled by engine inlet manifold pressure, applied to an inlet 211 and by fuel pressure across the impeller 206. The valve 208 is operated by these control parameters such that under engine starting conditions, the valve member 210 is lifted from the lower seat and allows adequate fuel supply to the engine even though the pressure difference across the impeller 206 is small. Under normal engine running conditions, the valve member 210 is maintained intermediate the seated positions, allowing free fuel flow, but under conditions in which the engine runs fast with the engine throttle closed, the valve member 210 seats on the upper seating and again cuts-off fuel supply.

A barometric compensation valve 212 is connected between the gas/air separator 209 and the fuel return branch 202 (points A—A) and adjusts fuel flow to the manifold 39 to compensate for atmospheric changes.

The fuel manifold 39 is connected by flow equalizing restrictors 38 to the fuel inlets of the injector devices 37 positioned as previously described with reference to FIGS. 5 and 6. The injector devices can be of the type shown in FIGS. 1–3 or that shown in FIG. 4. As previously mentioned, if the injectors are of the type shown in FIG. 1A, the flow restrictors 38 are omitted, their function being performed by the restrictors 13.

Downstream of the metering valve 203 the fuel return branch 202 includes an air valance valve 213 connected to a collection chamber 214 from which surplus fuel is returned to the tank 205 by a scavenge pump 215. A vacuum relief valve 216 connected to the collection tank 214 ensures that the scanvenge pump 215 does not starve the injector devices 37 of fuel.

The injector devices 37 are supplied with atomizing air from a compressor 217 (FIG. 8) connected to the air

supply line 40 (FIG. 5) which incorporates a vacuun relief valve 41, shown diagrammatically in FIG. 8.

The metering valve 203 has a valve member 219 operable in response to engine inlet manifold vacuum, connected to the valve 203 by conduit 220, to vary the fuebled to the return branch 202. Thus, fuel supply to the injector devices is dependent upon engine speed (impelle206) and engine inlet manifold vacuum pressure (valve 203). The vacuum relief valve 41 ensures that air pressure in the supply line 40 and in the injector devices 37 is at least atmospheric pressure. Since the air pressure in the injector devices opposes fuel flow therein, which could affect correct fuel supply to the engine, atomizing air pressure is fed to the relief valve 207 and the air balance valve 213 so that balanced fuel flow conditions are obtained throughout the ring circuit.

In both the fuel injection systems described above, fuel is continuously circulated in the ring main with the highest rate of circulation at high engine speed and low engine loading, ensuring that the system is self-cooling. The injector devices receive fuel in dependence with engine speed and engine inlet manifold vacuum, although some other suitable engine operating parameter could be used instead, at pressures typically rising to the order of 90 p.s.i. at the higher engine speeds. Atomizing air is fed to the open injector devices, typically at a pressure of about 3 p.s.i. in which the fuel is atomized by the air flow and injected continuously into the engine inlet ports. The injector devices have open nozzles, are simple in construction but are so designed that the air stream produces efficient atomization of the fuel and injection of fuel substantially at the atomizing air pressure, the latter being prevented from falling below atmospheric pressure by a vacuum relief valve and thereby preventing the manifold vacuum interfering with fuel flow through the injectors.

The systems described with reference to FIGS. 7 and 8 are described in greater detail in my co-pending application Ser. No. 482,994 filed Aug. 10, 1965 for Fuel Injection Systems. The control valve 208 (FIG. 8) is the subject of my co-pending application Ser. No. 434,596, filed Feb. 23, 1965, for Fluid Flow Control Valves and features of the metering valves 103 (FIG. 7) and 203 (FIG. 8) are disclosed in greater detail in my co-pending application Ser. No. 434,418, filed Feb. 23, 1965, for Metering Valves and Control Devices.

What is claimed is:

1. A low pressure continuous fuel injection system for an internal combustion engine having an inlet manifold structure subject to sub-atmospheric pressures, including a plurality of injector devices, each said injector device including a body portion, an air chamber defined in said body portion, an air inlet in said body portion communicating with said air chamber, an air tube projecting from said body portion and at the proximal end thereof communicating with said air chamber, the distal end of said air tube having an open, axially directed outlet orifice, a fuel tube extending from said body portion into and along said air tube in spaced relation therewith, the distal end of said fuel tube terminating short of said outlet orifice and defining a fuel outlet aligned with said outlet orifice, and a fuel inlet in said body portion communicating with said fuel tube, and in which said outlet orifices of said injector devices are disposed in said manifold structure so that the interiors of the air tubes of said injector devices are exposed to pressure conditions in said manifold structure, means for metering liquid fuel to the fuel inlets of said injector devices and means for supplying atomizing air to the air inlets of said injector devices to atomize the liquid fuel supplied thereto and discharge the atomized fuel through said outlet orifices at substantially atomizing air pressure, and vacuum relief valve means connected to the air inlets of said injector devices for ensuring that sub-atmospheric pressures in said man-

ifold structure do not result in sub-atmospheric pressures in the air tubes of said injector devices.

2. A system according to claim 1, in which the said fuel tubes include flow equalizing restrictor devices located adjacent the outlet ends thereof.

3. A system according to claim 1, in which each said fuel injector device includes a device external of the fuel tube locating the fuel tube in said air tube, the location device offering low resistance to air flow.

4. A fuel injection system according to claim 1, in which the air inlets of the injector devices are connected to said common atomizing air supply line in which is connected said vacuum relief valve for connecting atmospheric pressure to the air supply line when said valve is open.

References Cited

UNITED STATES PATENTS

2,745,210	5/1956	Hild	239—424 XR
2,859,741	11/1958	Glenn	123—119
2,893,365	7/1959	Haefner	123—119
3,022,013	2/1962	Bruinsma	239—424 XR
3,182,646	5/1965	Kuechenmeister.	

FOREIGN PATENTS

774,636	9/1934	France.
405,308	1/1934	Great Britain.

HARRY B. THORNTON, *Primary Examiner.*

R. R. WEAVER, *Examiner.*