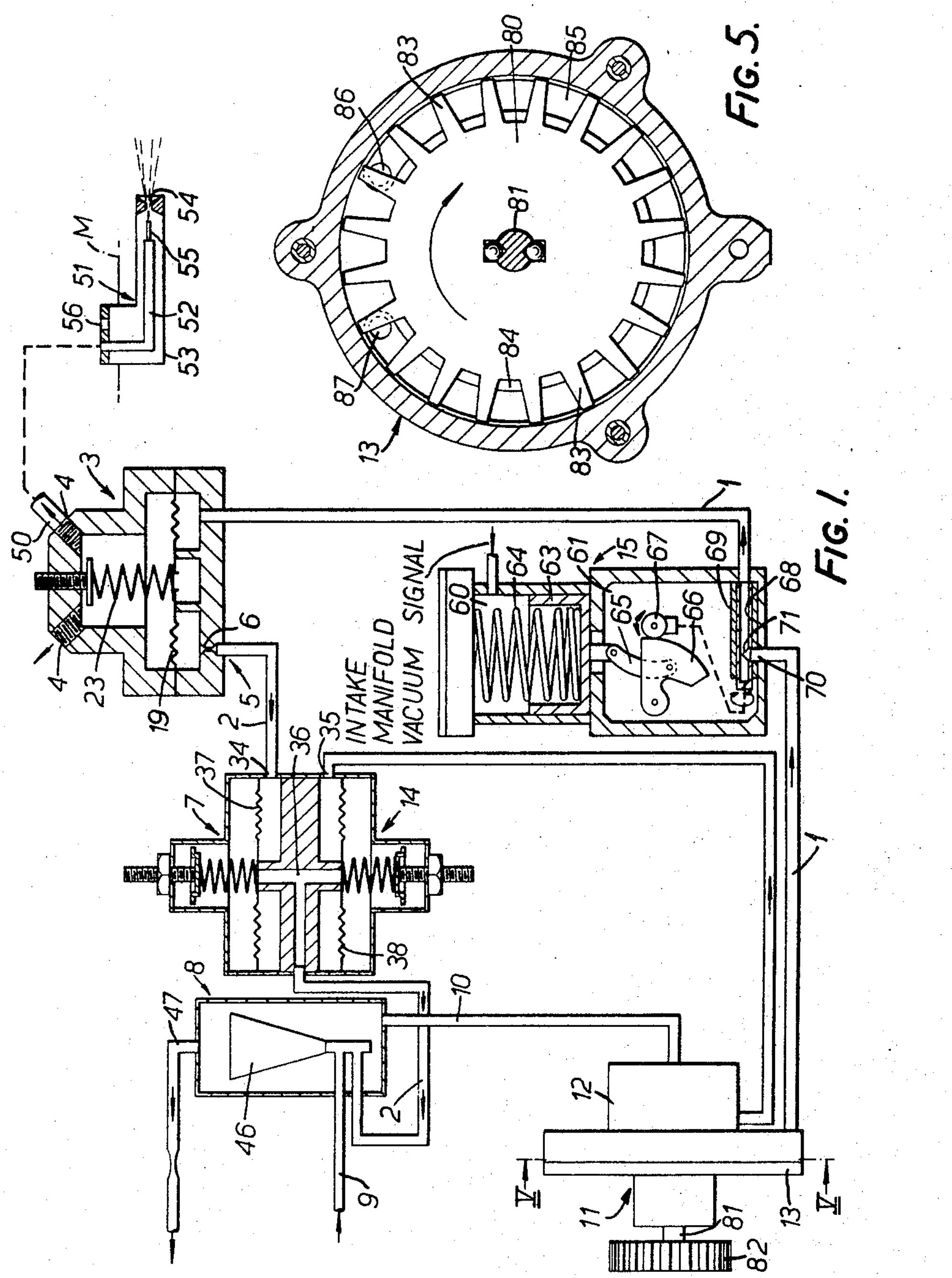
Dec. 17, 1968 H. E. JACKSON 3,416,504

FUEL INJECTION SYSTEMS

Filed Aug. 25, 1966 2 Sheets-Sheet 1



INVENTOR
H. E. Jackson
BY
Holcomb, Wetherill & Brisebois
ATTORNEY

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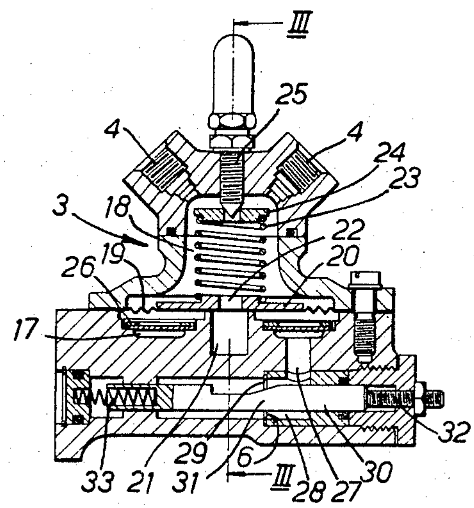

FIG. 2.

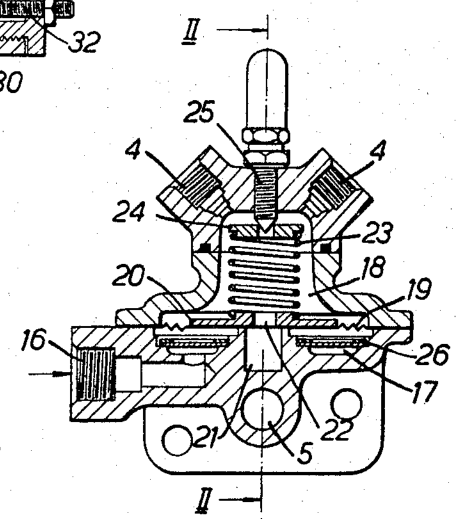

FIG. 3.

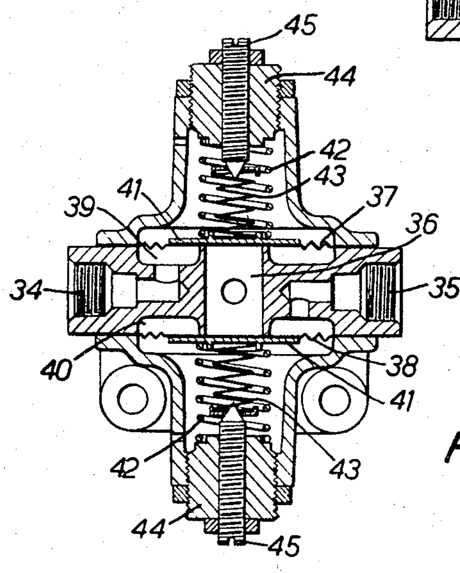

FIG. 4.

INVENTOR
H. E. Jackson
BY
Holcomb, Wetherill & Brisebois
ATTORNEY

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FUEL INJECTION SYSTEMS

Harold Ernest Jackson, Plympton St. Mary, Devon, England, assignor of one-half to Petrol Injection Limited, Plymouth, Devon, England

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ABSTRACT OF THE DISCLOSURE

A continuous circulation fuel injection system in which fuel supply to injector devices is pressurised in dependence on the square of engine speed by a rotary ring impeller and also controlled by a variable area orifice metering valve operated by engine air intake manifold vacuum. In order to eliminate vaporisation of fuel fed to the impeller devices, the supply branch is connected to the impeller devices by a chamber having a first compartment having an upstanding tubular portion against which a diaphragm is seated by a predetermined, constant force sufficient to ensure that fuel pressure in the supply branch does not fall below a predetermined value adequate to prevent fuel vaporisation. The diaphragm has an aperture located within the confines of the annular seating so that when the diaphragm is unseated, fuel flows from the first compartment through the diaphragm aperture to a second compartment and hence to the injector devices, fuel flowing from the second compartment having removed therefrom the said predetermined pressure. The first compartment is also connected to the fuel return branch which also includes a second diaphragm valve closed by the same predetermined force as the first mentioned diaphragm valve. In the system described fuel flow from the second diaphragm valve is to a vapour separator which has an upstanding funnel member the lower, constricted end of which receives fuel from the second diaphragm valve. The funnel member is disposed in a chamber having an upper vapour vent and a lower fuel outlet from which the fuel pressurising means is supplied.

This invention relates to continuous low-pressure fuel-inpection systems for internal combustion engines and also to components for use in such systems.

The specification of co-pending application S.N. 527,221 filed Feb. 14, 1966 describes a fuel injection system for an internal combustion engine which includes a fuel circulation conduit system having supply and return branches, and vented open fuel injector devices connected to the supply branch to receive fuel from it and each adapted to discharge such fuel into branch pipes leading from the engine intake manifold to the respective engine cylinders. That specification also describes how fuel is metered by pressurisation at relatively low pressures dependent on engine speed and by a fuel metering valve device to vary the fuel supply to the injector devices in dependence upon at least one other engine operating parameter, for example, engine intake air density represented by engine inlet manifold vacuum by pressure drop across a venturi in the manifold or by the engine throttle opening.

The temperature conditions under which such a system has to operate are sometimes such that vaporization of the fuel in the supply and return branches takes place and this prejudices the satisfactory operation of the system.

According to the present invention that disadvantage is minimised by increasing the pressure in the supply and return branches to a value sufficient to stop or substantially reduce vaporization. However, the pressure of fuel at the fuel injector devices must be of a lower value appropriate to the operation of the system and accordingly, the increased fuel pressure is reduced to the requisite low value just before the fuel reaches the injector devices. Pressure is returned to the higher value in the return branch.

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The supply branch of the fuel circulation conduit system can contain a chamber from which the injector devices are fed and which also includes a pressure removing device for returning the fuel pressure to the lower pressure required by the injector devices. The chamber can be divided into two parts by a resilient diaphragm loaded to a pressure equal to the added pressure to which the fuel is subjected to prevent or substantially reduce vaporization. The diaphragm controls fuel flow to the injector devices and is lifted by the fuel pressure in the supply branch to admit fuel to the injector devices at the lower pressure.

The return branch of the fuel circulation conduit system extends from an outlet in the chamber via a pressure loading valve—which raises the fuel pressure in the return branch to the increased value—and thence to the fuel tank. Preferably, a vapour separator is included in the return branch between the loading valve and the fuel tank to prevent any vapour which has formed being returned to the tank.

In one embodiment of the invention, the fuel circulation conduit system includes an engine driven fuel pump mechanism which in conjunction with a variable orifice metering valve meters fuel to the injector devices in dependence on engine speed and engine loading. Fuel pressure is adjusted in accordance with engine speed by the pump mechanism whilst fuel flow is adjusted by the metering valve in dependence on engine loading.

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

FIG. 1 shows the embodiment in diagrammatic form only,

FIGS. 2 and 3 are cross sections on the lines II—II and III—III respectively of FIGS. 3 and 2 of a component of the system of FIG. 1,

FIG. 4 is a section through another component of the system of FIG. 1, and

FIG. 5 is a section on the line V—V in FIG. 1.

The system shown in FIG. 1 includes a fuel circulation conduit system comprising a fuel supply branch **1** and a fuel return branch **2**. The supply branch **1** contains a distribution chamber **3** with exit orifices **4** joined by conduits **50** to fuel injection devices **51** located in branch pipes leading from the engine intake manifold to the respective engine cylinders. The injector devices each has a fuel tube **52** extending along an outer tube **53** terminating in an outlet orifice **54**. The fuel tube terminates in a capillary tube **55** (acting as a flow equalising restrictor) short of and aligned with the outlet orifice **54**. The outer tube **53** has a vent **56** to atmosphere. The capillary tube **55** has a bore size relative to that of the orifice **54** such that fuel emergent from the capillary tube is discharged through the outlet orifice without contacting the walls of the orifice. The injection devices shown are described in greater detail in the said copending application S.N. 527,221. The return branch **2** extends from an exit orifice **5** in the chamber **3** containing a flow restrictor **6** via a pressure loading valve **7** and a vapour separator **8** to the fuel tank of the engine (not shown).

Connected to the vapour separator **8** is an inlet pipe **9** leading from the usual engine-powered fuel lift pump (not shown) and also an outlet pipe **10** leading to the inlet of an engine driven fuel pump mechanism **11** which supplies fuel to supply branch **1** at a minimum pressure of the order of 10 p.s.i. This pressure increases with increasing engine speed. The pump mechanism **11** comprises a priming pump **12** which supplies fuel to a main pump **13** at a pressure determined by a pressure relieve valve **14** connected between the outlet of the priming pump **12** and the return branch **2**. The construction of the main pump **13** is shown in more detail in FIG. 5 which is a section on line V–V in FIG. 1. The pump has a rotor **80** keyed to a shaft **81** connected to a gear **82** (FIG. 1) adapted to be driven by the engine. The rotor **80** has circumferential vanes or teeth **83** and is mounted for rotation in a closely fitting shallow cylindrical chamber one end face **84** of which has an arcuate groove **85**, registering with the teeth **83**, describing an arc of about 305° around the end face **84**. One end of the groove **85** communicates with an inlet port **86**, fed from the priming pump **12**, and the other end communicates with an outlet port **87** leading to the supply branch **1**. In operation of the pump **13**, the rotor **80** is rotated at a speed determined by the engine speed and fuel entering the inlet port **86** is swept around the groove **85** by the teeth **83** as a speed dependent on engine speed. At the opposite end of the groove, the velocity energy of the fuel is converted to pressure energy, the fuel thereby being forced through the outlet port **87**. Thus, the pressure of fuel flowing through the outlet port is directly controlled by engine speed.

The output from the main pump **13** passes to the supply branch **1** which contains a fuel metering valve which is controlled by the engine inlet manifold vacuum or by the opening of the engine throttle to vary the area of a metering orifice in the supply branch **1** and thereby to adjust fuel flow to chamber **3** in dependence upon the inlet manifold vacuum or the throttle opening.

One version of a suitable metering valve **15** is functionally illustrated and has upper and lower chambers **60, 61**. The former chamber has an inlet **62** for connection to the engine air intake manifold to communicate manifold vacuum changes to the interior of chamber **60**, thereby causing movement of a piston **63** therein against a spring **64** in response to such changes. The piston **63** is coupled by a linkage **65** to a pivoted cam **66** in the chamber **61** so that movement of the piston causes the cam to pivot and to rotate a cam follower **67**. Rotation of the cam follower rotates a valve stem **68** in a sleeve **69**. The valve stem **68** is open at one end and closed at the other, the open end communicating with the supply branch **1** downstream of the valve **15**. Upstream of the valve **15**, the branch **1** communicates via a rectangular aperture **70** in the sleeve **69** with the interior of the valve stem **68** under control of a transverse slot **71** in the wall of the stem. The width of the slot **71** changes along its length so that rotation of the valve stem **68** in the sleeve **69** varies the area of the slot in registration with the rectangular aperture **70** and hence controls the flow of fuel through the metering valve **15**. This metering valve is described in greater detail in co-pending application S.N. 527,221.

FIGS. 2 and 3 show in more detail the chamber **3** and the valve contained therein. The chamber **3** has an inlet **16** leading to an annular inlet chamber **17** separated from an outlet chamber **18** by a resilient diaphragm **19** carrying a diaphragm disc **20**. The diaphragm **19** acts as a closure valve and controls flow of fuel from chamber **17** to chamber **18** via a central chamber **21** and a central opening **22** in both diaphragm **19** and disc **20**. The wall of the central chamber **21** forms a seating for the diaphragm which is loaded by a spring **23** located by the disc **20** and a spring plate **24**. The loading of the diaphragm **19** by the spring **23** is adjustable by an adjusting screw **25**. Also located in the chamber **17** is an annular shaped fuel filter **26**.

The chamber **17** has an outlet passage **27** leading to a chamber **28** containing an orifice disc **29** and an axially

adjustable rod **30** which passes through the disc **29** and has a portion **31** the cross sectional area of which transverse to the axis of the rod **30** changes along that axis and the position of which relative to the orifice disc **29** determines the rate of fuel flow through the latter. Thus, the rod **30** and the orifice disc **29** perform the function of the restrictor **6** in FIG. 1. The chamber **28** is connected to the outlet **5** leading to the return branch and which is located on that side of disc **29** remote from passage **27**. The position of rod **30**, and hence the effective area of the orifice **29**, is determined by the setting of an adjusting screw **32** against which the restrictor is held by a spring **33**.

Conveniently, the pressure loading valve **7** and the relief valve **14** are contained in a common housing which is shown in more detail in FIG. 4.

The housing has fuel inlets **34, 35** separated from a common outlet chamber **36** by spring-loaded resilient diaphragms **37** and **38** respectively. The inlet **34** communicates with an annular inlet chamber **39** the access of which to the outlet chamber **36** is controlled by the diaphragm **37** which coacts with a seating provided by the upper (as seen in FIG. 4) end of chamber **36**. Similarly, the inlet **35** communicates with an annular inlet chamber **40** the access of which to the outlet chamber **36** is controlled by the diaphragm **38** which coacts with a seating provided by the lower (as seen in FIG. 4) end of chamber **36**. The diaphragms **37, 38** both have diaphragm discs **41** which each support loading springs **42, 43** adjustable by adjusting nuts **44** and adjusting screws **45** respectively. The springs **42, 43** are relatively heavy and relatively light springs respectively, allowing very accurate adjustment of the pressure loading of the diaphragms **37, 38**.

The inlets **34, 35** are joined respectively to the return branch **2** (FIG. 2) leading from the outlet **5** and to the output of the priming pump **12**, whilst the outlet chamber **36** is joined by the return branch **2** to the vapour separator **8**.

The vapour separator **8** (FIG. 1) is of known form and comprises an inverted cone **46** connected at its apex to the return branch **2** and to the fuel inlet **9**. A restricted vapour venting connection **47** at the top of the separator permits the return of vapour from the separator to the fuel tank (not shown).

Before operation of the system, the pressure relief valve in the chamber **3** (as shown in FIGS. 2 and 3) is set so that the loading on diaphragm **19** is equal to the predetermined additional pressure to be applied to the fuel to prevent or substantially reduce fuel vaporization in the components of the system shown in FIG. 1 due to engine temperature. Thus, the fuel pressure in chamber **18** is equal to the low pressure necessary for effective atomisation of the fuel in the injector devices.

The pressure loading valve **7** ensures that the fuel pressure in the return branch **2** is sufficient to stop or substantially prevent vaporization in that branch. A pressure of the order of 10 lbs. per square inch is satisfactory for most conditions. If, due to overheating, vapour does form, it is separated out in the separator **8**.

In operation of the system described above, the diaphragm **19** determines the minimum fuel pressure in the supply branch **1** and the valve **7** ensures that a similar pressure exists in the return branch **2**. Fuel is metered to the injector devices **51** by the engine driven pump mechanism **11** acting in conjunction with the metering valve **15**. The pump mechanism adjusts fuel pressure in the supply branch with changes in engine speed and the metering valve **15** is controlled by engine air intake manifold vacuum to adjust fuel flow to the chamber **3** in dependence on engine loading. From the distribution chamber **3**, the fuel flow divides between the injector devices **51** and the return branch **2** in dependence upon the setting of the restrictor rod **30**, the restriction offered by the flow equalising restrictors **55** in the actual injector devices and the spring loading on diaphragm **37**. Pressure in the return branch is maintained by the valve **7** at the value necessary to stop or substantially prevent vaporization of fuel in the return branch under normal conditions of engine temperature.

I claim:

1. A low pressure continuous fuel injection system for an internal combustion engine including a plurality of fuel injector devices, a fuel circulation conduit system having supply and return branches; means connecting said supply branch to said injector devices for supplying fuel thereto; engine driven fuel pressurising means connected in said supply branch to circulate fuel through said conduit system and to deliver fuel to said supply branch at a pressure which increases with the square of engine speed and has a predetermined minimum pressure value sufficient substantially to prevent vaporisation of fuel in said supply branch during operation of the said engine; said circulation conduit system also including variable area orifice metering valve device responsive to changes in engine loading to adjust fuel flow from said supply branch to said injector devices in dependence on engine loading; a fuel distribution chamber having first and second compartments, means connecting the first compartment to the said supply and return branches; the said fuel distribution chamber including a first fuel pressure setting device comprising a first closure member movable between a first position in which it closes communication between the first and second compartments and a second position in which it communicates the first compartment with the second compartment, and resilient loading means urging said first closure member to said first position, said resilient loading means exerting seating pressure on said first closure member substantially equal to said predetermined minimum pressure value; said first and second compartments, when communicating, forming part of said means connecting said supply branch to said injector devices and in which said return branch includes a second fuel pressure setting device comprising a chamber having an outlet closable by a second closure member contained by said chamber, resilient means biasing said second closure member to close said outlet with a closure pressure substantially equal to said predetermined minimum pressure value; whereby fuel pressure in said supply branch between said fuel pressurising means and said first fuel pressure setting device and also in said return branch between said first compartment and said second fuel pressure setting device is always at least equal to said predetermined minimum pressure value during operation of said engine.

2. A system as claimed in claim **1**, wherein the said first compartment includes an upstanding annular seating and wherein said first and second closure members are respective first and second resilient diaphragms; said first diaphragm having an an aperture therein and said first position the said first diaphragm being urged by the said resilient loading means against said annular seating with the said seating surrounding said diaphragm seating.

3. A system as claimed in claim **2**, wherein said fuel metering device is connected in said supply branch and said means connecting said first compartment to said return branch comprises a fixed flow restrictor.

4. A system according to claim **3**, wherein said fixed flow restrictor comprises a member defining an orifice and an elongated member extending through said orifice to define together with said orifice an annular passage, and wherein said elongated member has a cross-sectional area which changes along part of the length thereof, and means operable to adjust the position of said elongated member relative to said orifice to set the flow resistance provided by said annular passage to a selected value.

5. A fuel injection system as claimed in claim **2**, wherein said engine driven fuel pressurising means comprises a feed pump, a pressurising impeller and a relief valve, said pressurising impeller having an output connected to said supply branch and an inlet connected to receive fuel from said feed pump, and said relief valve

being connected to said pressurising impeller input to maintain the pressure of fuel fed by the feed pump to said pressurising impeller approximately at said predetermined minimum pressure value.

6. A fuel injection system as claimed in claim **5**, wherein said pressurising impeller comprises a housing, a surface defined internally of the housing, an arcuate groove in said surface, a disc disposed adjacent said surface and mounted on an engine driven shaft for rotation therewith, said disc having spaced peripheral portions registering with said groove, and in which the arcuate groove has ends which communicate with the pressurising impeller device inlet and outlet respectively, said disc being rotatable to sweep fuel from said pressurising impeller device input along said arcuate groove at a velocity increasing with rotary speed of said engine driven shaft and to expel said swept fuel through said pressurising impeller device outlet at a pressure which increases with the square of the rotary speed of said disc.

7. A system according to claim **2**, wherein said fuel metering device comprises a metering orifice and a valve member rotatable to vary the area of said metering orifice, a chamber containing a member movable in response to changes in air intake manifold vacuum of said engine, means coupling said movable member to a cam member having a cam surface engaged by a cam follower carried by said valve member whereby movement of said movable member causes said cam to rotate said valve mem- to change the area of said metering orifice in response to changes in engine loading represented by changes in said manifold vacuum.

8. A system according to claim **2**, wherein the outlet of said second fuel pressure setting device is connected to the fuel inlet of a fuel vapour separator comprising a chamber having an upper vent outlet and a lower fuel outlet, said fuel inlet being connected to the constricted end of a funnel shaped member disposed within said chamber, and wherein the funnel shaped member has a mouth disposed adjacent to vent outlet of said chamber.

9. A system as claimed in claim **1**, wherein said fuel pressurising means comprises a housing containing a disc mounted on an engine driven shaft, and having spaced peripheral portions, said disc being located adjacent a groove defined within said housing with said spaced peripheral portions registering with said groove, a feed pump connected to feed fuel to one end of said groove and the other end to effect a corresponding variation in area of said metering orifice; and a fuel vapour separator device comprising a funnel shaped member disposed in a chamber having a lower fuel inlet, a lower fuel outlet and an upper vapour vent, the funnel shaped member being located in the chamber with the constricted end of the funnel shaped member beneath the mouth thereof, the said constricted end of the funnel shaped member being connected to the said fuel inlet of said chamber and said groove being connected to said supply branch whereby fuel fed to the groove by said feed pump is swept around said groove by rotation of said disc and expelled from the said other end of the groove to said supply branch at a pressure increasing with the square of engine speed, a relief valve connected to the outlet of said feed pump to maintain the pressure of fuel fed by the feed pump to the said one end of said arcuate groove approximately at said predetermined minimum pressure value; wherein said fuel metering valve device comprises a member movable in response to air intake manifolds vacuum changes of said engine, a metering orifice and a valve member rotatable to adjust the area of said metering orifice, and means coupling said movable member with said rotary valve member whereby movement of said member in response to changes in said manifold vacuum causes rotation of said valve member to effect a corresponding variation in area of said metering orifice; and a fuel vapour separator device comprising a chamber containing a funnel shaped member, the chamber having an upper vapour vent and a lower fuel outlet, the funnel shaped member having a constricted end disposed nearer the said fuel outlet and a mouth end disposed nearer the said vent, and the outlet of said second fuel pressure setting device being connected to the said constricted end of the funnel shaped member to supply fuel thereto.

10. A system according to claim **9**, wherein the fuel metering valve device has a said movable member comprising a piston slidable in a chamber exposed to changes in said manifold vacuum, means coupling said piston to a cam having a cam surface engaged by a cam follower carried by said rotary valve member whereby sliding movement of said piston causes movement of said cam to rotate the said rotary valve member.

References Cited

UNITED STATES PATENTS

2,566,012	8/1951	Winkler et al.	123—119
2,895,463	7/1959	Powell et al.	123—139.17
2,898,899	8/1959	Karpiej	123—139.17
3,006,329	10/1961	Armstrong et al.	123—139.17
3,285,233	11/1966	Jackson	123.—139.17
3,311,099	3/1967	Beaber	123—119

LAWRENCE M. GOODRIDGE, *Primary Examiner.*

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123—119, 140