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Jackson

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[54] **FUEL INJECTION SYSTEMS FOR INTERNAL COMBUSTION ENGINES**

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[30] **Foreign Application Priority Data**

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[51] **Int. Cl.**^{2} **F02M 51/00**

[58] **Field of Search** ....123/140 MP, 139 AW, 139 AF, 123/119 R, 32 EA

[56] **References Cited**

UNITED STATES PATENTS

2,456,605	12/1948	Wirth et al.	123/139 AW
2,655,907	10/1953	Downing	123/140 MP
2,681,647	6/1954	Wille	123/139 AW
2,706,976	4/1955	Gianini	123/139 AW
2,727,504	12/1955	Peras	123/140 MP
3,712,275	1/1973	Jackson	123/119 R
3,721,390	3/1973	Jackson	239/585

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Assistant Examiner—David D. Reynolds
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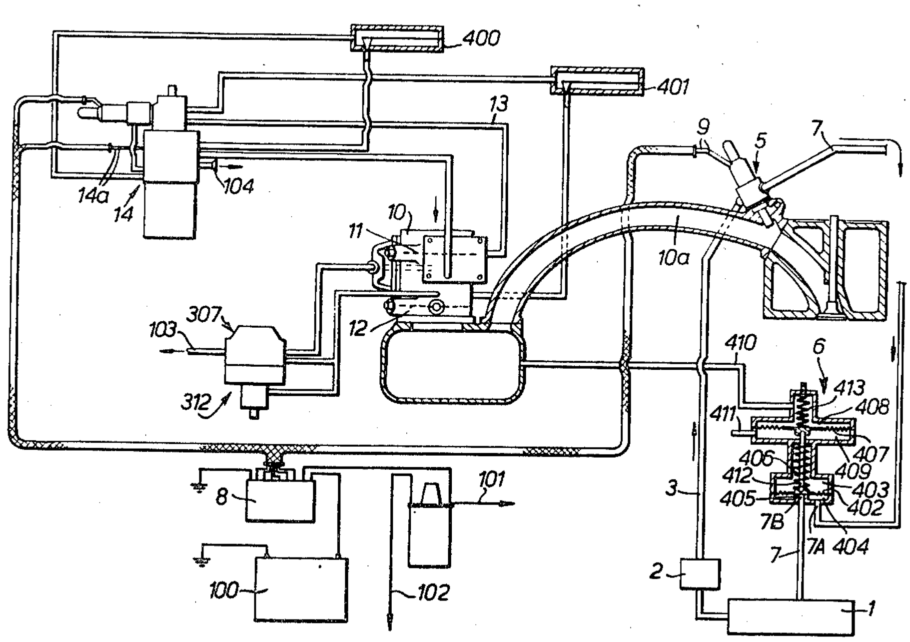
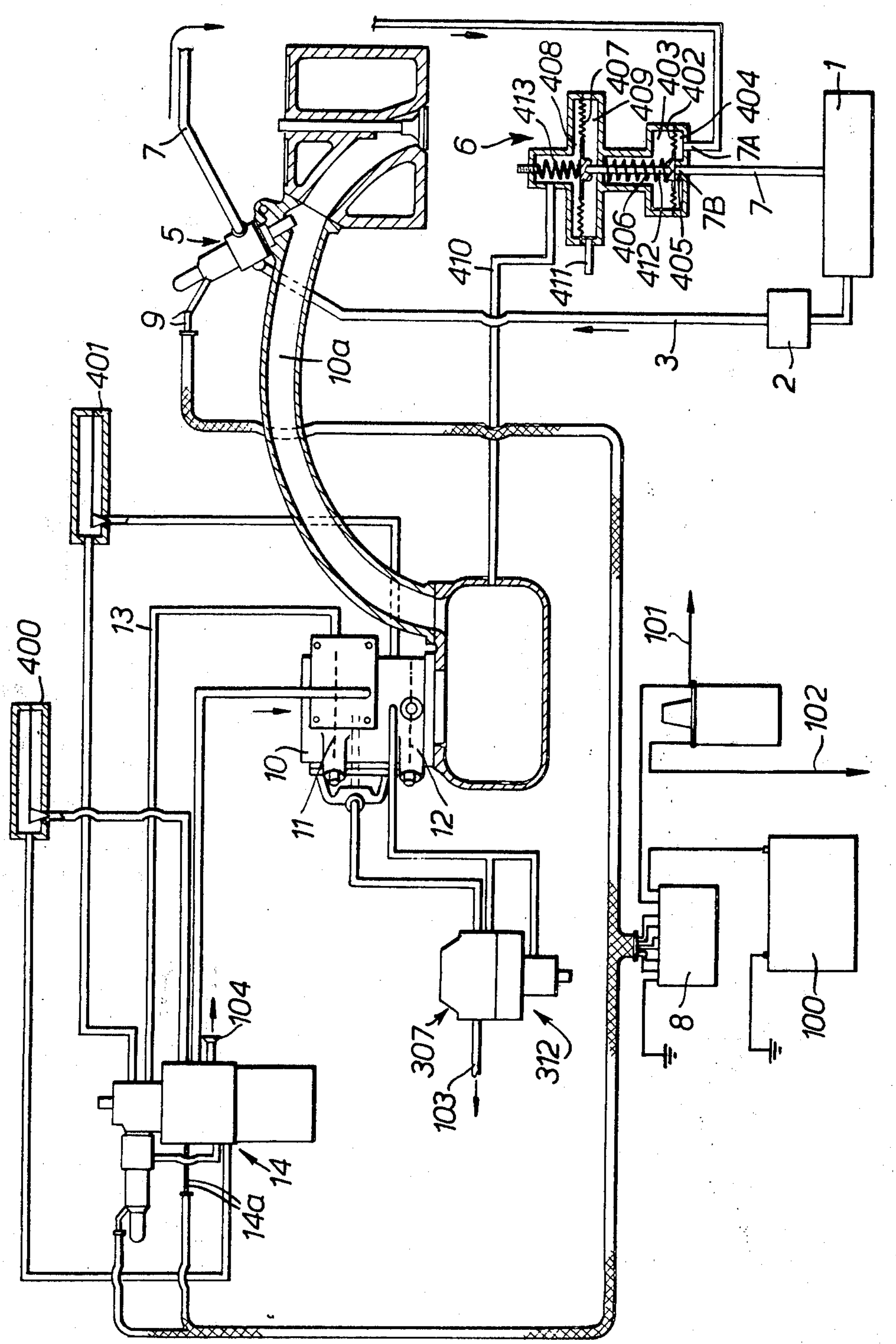
[57] **ABSTRACT**

A fuel injection system for an internal combustion engine, in which, for the purpose of modifying the fuel/air ratio only under certain engine conditions, the return branch of the fuel circulation system includes a resiliently-biased valve member which functions to maintain the return branch fuel pressure at a value dependent on the resilient bias, and means for varying the resilient bias under the said engine conditions. In an embodiment, the bias on the valve member is increased when intake manifold vacuum drops below a predetermined value, enabling fuel enrichment to be achieved when the engine is developing full power.

4 Claims, 1 Drawing Figure

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FUEL INJECTION SYSTEMS FOR INTERNAL COMBUSTION ENGINES

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

It is desirable to provide, in a fuel injection system, an arrangement for adjusting the ratio in which fuel and air are supplied to the engine so that, for example, a degree of fuel enrichment can be achieved under full throttle conditions. Such an arrangement may be manually controlled or it may come into operation automatically in response, for example, to throttle opening.

It is an object of the present invention to provide an arrangement which enables the fuel/air ratio to be modified automatically in response to a predetermined change in an engine operating parameter.

The invention provides a fuel injection system for an internal combustion engine, including a fuel circulation conduit system having supply and return branches, at least one injector device connected to receive fuel from the supply branch, and a fuel pressurizing device operable to supply fuel under pressure to the supply branch, the return branch including a valve closure member resiliently biased towards a closed position and movable against the resilient bias by fuel pressure in the return branch to permit fuel flow through the return line to an extent sufficient to maintain the return branch fuel pressure upstream of the valve closure member at a predetermined valve dependent on the said resilient bias, and means operable to vary the resilient bias in response to a variation in an engine operating parameter over part only of the range of that parameter.

The invention enables the amount of fuel discharged by the system to be modified under certain engine operating conditions and, more especially, enables the amount of fuel discharged to be increased when the engine is developing full power. To this end, the said means is operable to increase the resilient bias on the valve closure member in response to a drop in engine intake manifold vacuum to below a predetermined value. In an embodiment of the invention, the said resilient bias is substantially constant when the said means is unoperated, and the said means is operable to vary the resilient bias continously with variations in the engine operating parameter over the said part of the range of that parameter.

The valve closure member may be a resilient diaphragm resiliently biased by a spring.

The means operable to vary the said resilient bias may comprise a second resilient diaphragm which, when operated, is coupled to the valve closure member to vary the said resilient bias. The second resilient diaphragm may be biased towards the operative position by a spring. In an embodiment of the invention, the second resilient diaphragm is exposed on one side to engine intake manifold vacuum.

The injector device (s), may be operable to discharge fuel intermittently. The injector device(s), may, for example, be of the type described in U.S. Pat. No. 3721390 of Mar. 20, 1973 to Harold Ernest Jackson and may be operated by a control mechanism of the type described in U.S. Pat. No. 3,712,275 of Jan. 23, 1973 to Harold Ernest Jackson.

By way of example, a fuel injection system constructed in accordance with the invention will be described with reference to the accompanying drawing which is a diagram of the system.

The system shown in the drawing is of the type described in the above mentioned U.S. Pat. No. 3,712,275 and reference may be made to that Patent for a detailed disclosure of various components of the system.

Basically, the fuel circulation path of the system includes a tank **1** from which fuel is drawn by a pump **2** (which may, for example, be an electrically-driven gear pump) and passed, at a substantially constant pressure to a supply conduit **3**. A plurality of injector devices **5** (only one of which is shown in the drawing) are connected in the supply conduit **3** and, in operation, discharge fuel into the intake manifold system of the engine. More particularly, as shown in the drawing, each injector device **5** is positioned to discharge fuel into a respective cylinder intake branch **10***a* of the manifold system. Excess fuel, that is fuel which is not discharged by the injector devices is returned to the tank **1** through a return conduit **7** including a relief valve **6**. The construction of the relief valve **6** differs from that described in the above-mentioned U.S. Pat. No. 3,712,275 and will, accordingly, be described in greater detail below.

The injector devices **5** are air-bled solenoid-operated devices of any suitable form but preferably of the type described in the above mentioned U.S. Pat. No. 3,721,390. In use, the injector devices **5** discharge fuel intermittently under the control of electrical pulses produced by a switching unit **8** to which each device is electrically-connected by leads **9**. The switching unit **8** is connected to the battery **100** and also, through leads **101** and **102** respectively, to the contact breaker and ignitionn switch of the conventional contact breaker circuit whereby the control pulses are generated at a rate dependent on engine speed. The length of the pulses, and hence the length of time for which the injector devices **5** discharge fuel, is adjusted with engine air intake. Details of the adjustment of the control pulse length are not necessary to an understanding of the present invention and may be obtained from the above-mentioned U.S. Pat. No. 3,712,275. Briefly, however, it may be mentioned that engine air intake is represented, for the purposes of adjusting the control pulse length, by the orientation of an air valve located in the engine air intake conduit **10** upstream of the customary throttle valve. The positions of the air and throttle valves are indicated at **11** and **12** respectively. When the engine is in operation, the air valve **11** produces a control depression in the intake conduit **10** and the position of the air valve is adjusted, in response to a variation in the control depression from a predetermined valve, to return the depression to that predetermined valve. This adjustment of the air valve **11** is effected by a sensing valve **312** and servomechanism **307** and is accompanied by adjustment of a metering valve (not shown) controlling the rate at which air flows through a control line **13**, which air flow in turn controls operation of a timing switch **14**. The timing switch **14** is electrically-connected to the switching unit **8** by leads **14***a* and determines the length of the control pulses produced by that unit. The servomechanism **307** and the timing switch **14** both communicate, through conduits **103** and **104** respectively, with the intake conduit **10** immediately downstream of the customary air cleaner (not shown) but this has no bearing on the present invention. If required, details of the construction and function of the components **307**, **312**, **13** and **14** can be obtained from the above mentioned U.S. Pat.

No. 3,712,275.

Associated with the timing switch **14** are valves **400, 401** which modify operation of the timing switch in the manner described in U.S. Pat. No. 3,712,275, and thereby adjust the length of the control pulses, under certain engine conditions. The valves **400, 401** may, for example, be responsive to intake manifold temperature and cooling water temperature respectively. It should be noted, however, that a separate valve for modifying operation of the timing switch **14** to achieve fuel enrichment when the engine is operating under full load is not included in the system since the function of such a valve is fulfilled by the relief valve **6**.

The main portion of the relief valve **6** includes a valve closure member in the form of a resilient diaphragm **402** which separates two chambers **403** and **404** within the relief valve. The inlet **7A** of the relief valve opens directly into the chamber **404** while the outlet of the relief valve is a port **7B** surrounded by an upstanding valve seating **405** within the chamber **404**. When the system is not operating, a spring **406** in the chamber **403** biases the diaphragm **402** against the valve seating **405** as shown in the drawing, in which position the disphragm cuts-off communication between the inlet **7A** and outlet **7B** of the relief valve.

A second resilient diaphragm **407** separates two further chambers **408** and **409** within the relief valve, of which the chamber **408** communicates through a conduit **410** with the engine air intake manifold downstream of the throttle valve **12** and is, accordingly, exposed to intake manifold vacuum while the chamber **409** communicates through a conduit **411** with the intake conduit **10** immediately downstream of the customary air cleaner (not shown). The diaphragm **407** carries a push-rod **412** which extends through the chamber **409** and into the chamber **403** of the main valve portion. When the system is not operating, a spring **413** in the chamber **408** biases the second diaphragm **407** into a position in which, as shown in the drawing, the push rod **412** engages the first diaphragm **402**.

When the engine is operating under part-load conditions and intake manifold vacuum is comparatively high, a pressure differential exists across the second diaphragm **407**, which opposes and is sufficient to overcome the action of the spring **413**. The diaphragm **407** accordingly moves against the spring **413**, taking the rod **412** out of engagement with the first diaphragm **402**. The pump **2** delivers fuel to the supply conduit **3** and the fuel is discharged intermittently by the injector devices **5** as already described. The excess fuel passes along the return conduit **7** and into the chamber **404** of the relief valve **6**, where the fuel pressure acts on the diaphragm **402** in opposition to the spring **406**. When the fuel pressure in chamber **404** is sufficient to overcome the action of the spring **406** the diaphragm **402** moves away from the upstanding seating **405** to permit fuel to flow from the chamber **404** to the tank **1**. If the pressure in chamber **404** increases further, the diaphragm **402** moves further away from the seating **405** to increase the return flow to the tank **1** whereas if the pressure in chamber **404** decreases the diaphragm **402** moves back towards the seating to decrease the return flow. The characteristics of the spring **406** are chosen so that the biasing force exerted by the spring is substantially constant over the range of positions of the diaphragm **402**: as a result, a predetermined substantially constant fuel pressure is maintained upstream of the relief valve **6** provided that the push rod **412** remains out of engagement with the diaphragm **402**. The existence of this substantially constant pressure which, typically, is of the order of **20** p.s.i. ensures that the amount of fuel discharged by the injector devices **5** during each operating period depends solely on the length of that period.

The force exerted on the second diaphragm **407** by the spring **413** is comparatively weak and is not sufficient to move the push rod **412** into engagement with the first diaphragm **402** until the throttle valve **12** is approaching the fully-open position and intake manifold vacuum has dropped to a comparatively low value (typically 5'' Hg.). When this occurs, the biasing force exerted by the spring **406** on the diaphragm **402** has added to it the resultant force on the diaphragm **407** (equal to the difference between the force exerted by the spring **413** and the opposite, weaker, force due to manifold vacuum). As a result, the diaphragm **402** moves towards the seating **405** and the fuel pressure upstream of the relief valve **6** rises from the substantially constant value referred to above by an amount corresponding to the aforesaid resultant force on the diaphragm **407**. The increase in fuel pressure upstream of the relief valve **6** results in an increased amount of fuel being discharged by the injector devices **5** during each operating period or, in other words, in the required fuel enrichment under full throttle conditions.

If the throttle valve **12** opens still further, inlet manifold vacuum falls further and the aforesaid resultant force on the diaphragm **407** increases further, bringing about a further increase in the amount of fuel discharged by the injector devices **5**. If, on the other hand, the throttle valve **12** closes and intake manifold vacuum rises by an amount sufficient to take the push rod **412** out of engagement with the diaphragm **402** then fuel pressure upstream of the relief valve **6** returns to the predetermined substantially constant valve referred to above.

It will be seen from the above description that the relief valve **6** acts directly on the fuel pressure to bring about the required fuel enrichment under full throttle conditions and, moreover, that the degree of fuel enrichment exhibits a desirable variation with intake manifold vacuum.

It will be appreciated that the use of a relief valve such as that shown at **6** in the drawing is not restricted to systems of the type described in U.S. Pat. No. 3,712,275 and is not even restricted to systems in which fuel is injected intermittently, but could be used with advantage in any system in which the quantity of fuel delivered to the engine is influenced by fuel pressure.

I claim:

1. A fuel injection system for an internal combustion engine, of the type including a fuel circulation conduit system having supply and return branches, at least one injector device connected to receive fuel from the supply branch, a fuel pressurizing device operable to supply fuel under pressure to the supply branch, and valve means including a valve closure member which is connected in the return branch and is resiliently biased towards a closed position, the valve closure member being exposed to the fuel pressure upstream in the return branch and being movable against the said resilient bias by that fuel pressure to an extent sufficient to maintain that fuel pressure at a predetermined value dependent on the said resilient bias, the system being characterized by means exposed to engine intake manifold vacuum and movable, in response to a drop in manifold vacuum to below a predetermined value, into co-operation with the valve closure member to increase the said resilient bias and thereby increase the said fuel pressure upstream in the return branch.

2. A system as claimed in claim **1**, in which, when the said means is unoperated, the said resilient bias is substantially constant, the said means being co-operable with the valve closure member to increase the resilient bias continously with decreasing manifold vacuum.

3. A system as claimed in claim **1**, in which the valve closure member is a resilient diaphragm and is resiliently biased by a spring.

4. A system as claimed in claim **1**, in which the valve closure member is a first resilient diaphragm, and said means comprises a second resilient diaphragm which is exposed to engine intake manifold vacuum and a push-rod which is mounted on the second resilient diaphragm and is co-operable with the first diaphragm to increase the said resilient bias.

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