April 7, 1959 J. B. CLARK, JR 2,880,714

FUEL INJECTION SYSTEM

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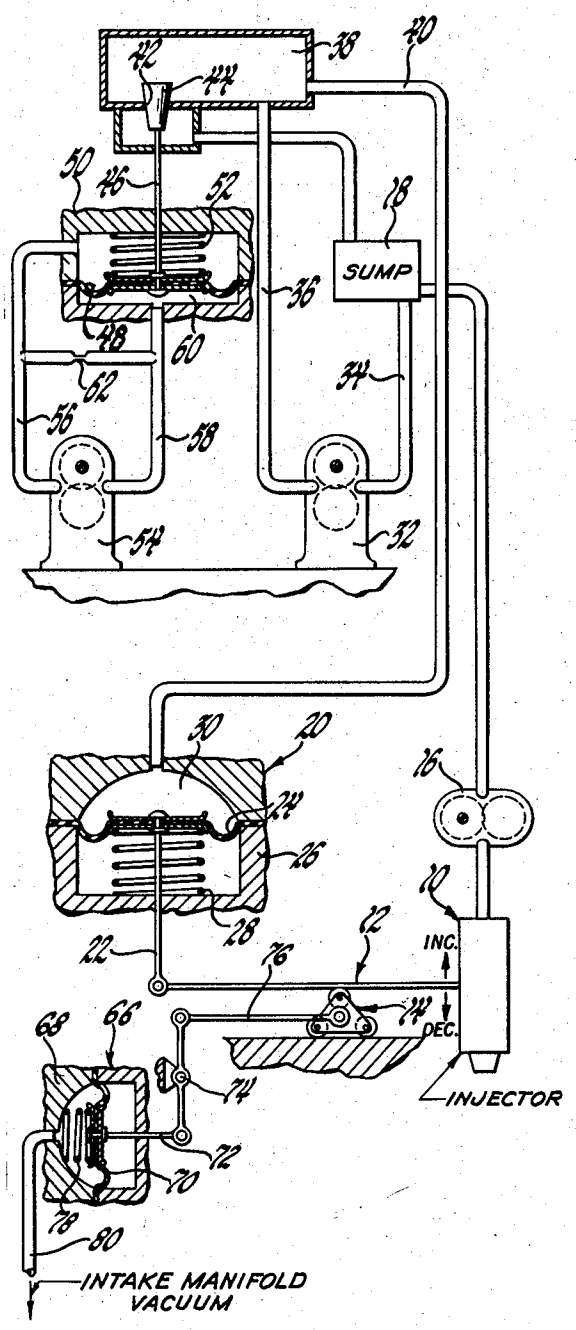


Fig. 1

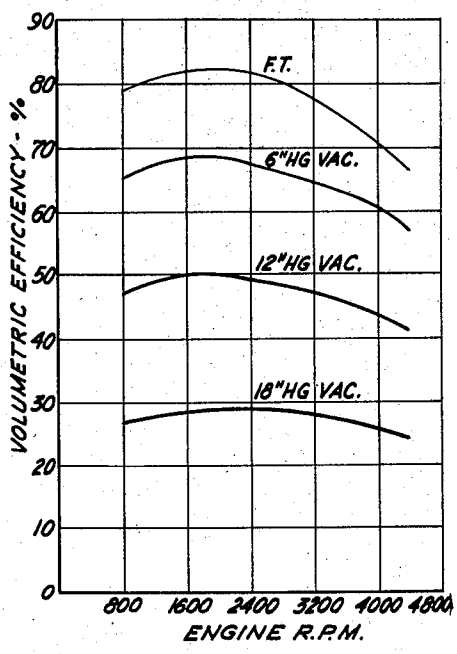


Fig. 2

INVENTOR.
John B. Clark, Jr.
BY
R. T. Barnard
ATTORNEY.

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FUEL INJECTION SYSTEM

John B. Clark, Jr., Ferndale, Mich., assignor to General Motors Corporation, Detroit, Mich., a corporation of Delaware

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8 Claims. (Cl. 123—140)

The present invention relates to a fuel metering system for an internal combustion engine which utilizes an injector for delivering a metered quantity of fuel to each cylinder of the engine. This invention is particularly directed to such an injector device in which the quantity of fuel supplied is determined by the speed of the engine as well as the load thereon. The density of the air in the intake manifold is wholly a function of load, thus such density may be used as a control force in combination with engine speed for regulating the quantity of fuel supplied by said injector.

In an internal combustion engine it has been found that as the engine speed increases beyond a given value the quantity of air inducted into the cylinders is no longer proportional to the speed and begins to fall off. This decrease in the quantity of inducted air results in a decrease in volumetric efficiency of the engine. It is theorized that the decreased quantity of air inducted at higher speeds is due to turbulence created in the intake passage. Whatever its cause, the resultant decrease in volumetric efficiency is well established. It is apparent that an injector control system should deliver fuel along a curve similarly shaped to the volumetric efficiency curve in order to insure a constant fuel-air ratio. In most fuel injection systems of the speed-density type, however, the decrease in volumetric efficiency with increased engine speeds has been ignored. The failure to accommodate the fuel supply system to a change in volumetric efficiency results in an unnecessarily rich fuel-air ratio with a consequent loss in economy as well as a loss in power performance.

It is the purpose of the present invention to provide a fuel injection system in which the quantity of fuel supplied by the injector is made responsive to variations in volumetric efficiency.

The present fuel supply system provides a device for injecting a metered quantity of fuel to each engine cylinder during each combustion cycle, a pressure responsive means operatively connected to said device to vary the quantity of fuel output per cycle, means for creating a control pressure which is a function of and increase with engine speed, a means for modulating said control pressure in accordance with engine speed to create a resultant control pressure proportional to the volumetric efficiency of the engine and further providing conduit means for conveying said resultant pressure to the pressure responsive means.

The details of the present invention as well as other objects and advantages will be apparent from the description which follows.

In the drawing:

Figure 1 is a diagrammatic representation of a fuel injection system embodying the present invention; and

Figure 2 illustrates the relationship between volumetric efficiency and engine speed.

The concepts of the present invention are applicable to any type of speed-density fuel injection system and the present diagrammatic representation is merely for the purpose of simply illustrating the basic principles of the invention. An injector for each cylinder of the engine is shown generally at **10**. The details of the injector, per se, constitute no part of the present invention and may be of any well known type such as that employing a plunger which is adapted to be pumped at engine speed to supply a metered charge of fuel for each combustion cycle of the associated cylinder. In this type of injector means is provided for varying quantity of charge which the plunger may pump per cycle. Typical of injectors which may be used are those shown in the copending applications Serial Number 597,237, Groves, filed July 11, 1956, and Serial No. 512,448, Dolza, filed June 1, 1955, now abandoned.

In the present system a lever **12** is provided which is suitably connected to the injector **10** to vary the quantity of the cyclic charge of the injector and which lever is pivoted about an adjustable fulcrum indicated generally at **14**. It is the means whereby lever **12** is controlled which constitutes the subject matter of the present invention. Before passing on to a description of the lever control system it should be noted that fuel may be supplied to the injector **10** by any suitable source of low pressure fuel through a make-up or supply pump **16** from a sump **18**.

A pressure responsive device or servo is shown at **20**, and includes a rod **22** suitably articulated to lever **12** and centrally fixed at its other end to a diaphragm **24** peripherally supported within a casing **26**. A spring **28** is disposed in casing **26** and is adapted to bias against diaphragm **24** to move the latter as well as rod **22** upwardly and pivot the control lever **12** in a clockwise direction about its fulcrum **14**. This type of movement of the control lever is in a direction to decrease the quantity of fuel supplied by the injector **10**. The bottom side of the diaphragm **24** is open to atmosphere. The upper side of the diaphragm **24** defines a chamber **30** with the casing **26** and which chamber is adapted to be subjected to a pressure bearing a given relation, infra, to engine speed and volumetric efficiency. In general, the pressure in chamber **30** increases with an increase of engine volumetric efficiency so as to move the diaphragm **24** and rod **22** downwardly to rotate the control lever in a counterclockwise direction against the control force of spring **28** to increase the quantity of fuel supplied by injector **10**.

In order to provide a basic control force or pressure which is proportional to engine volumetric efficiency, a first engine speed responsive pump **32** is provided which has an intake conduit **34** leading from the sump and an output passage **36** communicating with a reservoir **38**. Reservoir **38** includes an output conduit **40** communicating with diaphragm chamber **30** in casing **26**. Reservoir **38** also includes an orifice opening **42** which permits the fluid supplied by pump **32** to be returned to the sump at a rate determined by a contoured adjustable control element **44** which projects through the orifice **42**. Assuming for the moment that orifice **42** and element **44** together defined a fixed restriction, then a control force or pressure would be created by pump **32**, for transmission to diaphragm **24**, which would be a function of and increase with engine speed. However, as already noted such type of control pressure fails to take into account the decrease in volumetric efficiency at increased engine speeds due to the inability of the air induction system to supply air in direct proportion to speed. The relationship of volumetric efficiency to engine speed is graphically illustrated by the family of curves shown in Figure 2. From these curves it is seen that at a given manifold vacuum, volumetric efficiency decreases above a

given speed. The orifice control element 44 is made adjustable so as to reflect the change, e.g. decrease at higher engine speeds, in volumetric efficiency and to tailor the fuel supplied per combustion cycle to the decreased quantity of air.

The shape or contour of the adjustable element 44 is made to provide a flow rate through the orifice 42 such that the pressure within the reservoir 38 will reflect the change in volumetric efficiency as engine speed increases and further which change is manifested by a resultant control force in conduit 40 which will cause the quantity of fuel per combustion cycle supplied by injector 10 to be tailored to the reduced quantity of air being supplied to each cylinder per combustion cycle at increased engine speeds and to thereby maintain a substantially constant fuel-air ratio.

In order that the position of the adjustable element 44 be variable in accordance with engine speed a control rod 46 is suitably fixed thereto and the latter connected at its other end to a diaphragm 48 mounted within a support casing 50. A spring 52 is mounted in casing 50 and is adapted to bias diaphragm 48 and rod 46 in a downwardly direction to cause the element 44 to restrict the flow through orifice 42.

A second engine speed responsive pump 54 is provided which circulates a fluid through a closed circuit including an input passage portion 56 and an output passage portion 58. The output passage 58 is in communication with the diaphragm chamber 60. A fixed orifice 62 is provided in the closed control circuit between the input and output passages 56 and 58. Therefore, the pressure drop across orifice 62 is conveyed to the diaphragm 48 and since such pressure drop will be a function of and increase with engine speed the position of the adjustable element 44 with respect to orifice 42 will be determined by engine speed. As engine speed increases, therefore, element 44 is moved to increase flow through orifice 42 decreasing the pressure in passage 40 and thereby reducing the fuel supplied by injector 10 at higher engine speeds.

In order that the control lever 12 also reflect engine load, engine load responsive means 66 is provided to vary the position of the adjustable fulcrum 14. Engine load responsive means 66 includes a casing 68 having a diaphragm 70 peripherally supported therein and centrally secured to which diaphragm is a rod 72. Rod 72 is suitably articulated to a pivoted lever 74 which through a lever 76 connects with the adjustable fulcrum 14. A spring member 78 is disposed in casing 68 and biases the diaphragm 70 to the right so as to move the adjustable fulcrum 14 to the left. In this way the movement of the right end is multiplied by the increased moment arm between the fulcrum 14 and the injector 10 increasing the quantity of fuel supplied by the injector.

A conduit 80 communicates with the casing 68 and is adapted to be suitably connected with the engine intake manifold whereby manifold vacuum will act on the diaphragm 70 in opposition to the force of spring 78. Thus as the manifold vacuum increases the diaphragm will be moved to the left shifting the adjustable fulcrum 14 to the right to decrease the quantity of fuel supplied by injector 10 consistent with the decreased load on the engine as manifested by the increase in manifold vacuum.

Thus the present fuel injection system provides a resultant injector control force which is proportional to engine speed and load as modified to reflect the decreased volumetric efficiency which occurs at higher engine speeds.

It is apparent that the inventive concept embodied in the present invention is not limited to the type of diagrammatic system used for illustrative purposes and further that the scope of the invention is to be limited only by the hereinafter appended claims.

I claim:

1. A fuel metering system for an internal combustion engine comprising injector means for delivering metered quantities of fuel to each cylinder of the engine, a control member for regulating the quantity of metered fuel supplied by the injector means, a servo for actuating said member, a first engine speed responsive pump, conduit means communicating said pump and servo, an orifice associated with said conduit means, said orifice being variable in accordance with changes in volumetric efficiency of the engine, pressure responsive means for controlling the size of said orifice, a second speed responsive pump, and conduit means communicating with said second pump and said pressure responsive means to open said variable orifice in a fixed relation to engine speed.

2. A fuel metering system for an internal combustion engine comprising injector means for delivering metered quantities of fuel to each cylinder of the engine, a control member for regulating the quantity of metered fuel supplied by the injector, a diaphragm, means operatively connecting said diaphragm and control member, spring means biasing said diaphragm to decrease the fuel output of the injector means, a first engine speed responsive pump, conduit means communicating said pump and diaphragm whereby the pressure of said pump opposes the force of said spring, an orifice associated with said conduit means, said orifice being variable in accordance with changes in volumetric efficiency of the engine, pressure responsive means for controlling the size of said orifice, a second speed responsive pump, and conduit means communicating said second pump and said pressure responsive means to open said variable orifice in a fixed relation to engine speed and to thereby modify the pressure output of the first pump.

3. A fuel metering system as set forth in claim 2 in which said variable orifice comprises a fixed opening in said first pump conduit means, a contoured element projecting within and movable relative to said opening, a casing having a diaphragm therein, means connecting said diaphragm and contoured element, means biasing said element to restrict said opening, said second pump conduit means communicating with said diaphragm to cause the second pump pressure to increase flow through said opening as engine speed increases and to thereby modify the pressure output of the first pump.

4. A fuel metering system for an internal combustion engine comprising an injector for delivering metered quantities of fuel to each cylinder of the engine, a control member for regulating the quantity of metered fuel supplied by the injector, a servo for actuating said member, a first engine speed responsive pump, conduit means communicating said pump and servo, an orifice associated with said conduit means, said orifice being variable in accordance with changes in volumetric efficiency of the engine, pressure responsive means for controlling the size of said orifice, a second engine speed responsive pump, conduit means communicating said second pump and said pressure responsive means to open said variable orifice in a fixed relation to engine speed, and manifold vacuum responsive means for modifying the operation of said control member whereby an increase in manifold vacuum will decrease the fuel output of said injector for a given engine speed.

5. A fuel metering system for an internal combustion engine comprising an injector for delivering metered quantities of fuel to each cylinder of the engine, a control member for regulating the quantity of metered fuel supplied by the injector, an adjustable fulcrum for said member, a servo for pivoting said member about said fulcrum, a first engine speed responsive pump, conduit means communicating said pump and servo, an orifice associated with said conduit means, said orifice being variable in accordance with changes in volumetric efficiency of the engine, pressure responsive means for controlling the size of said orifice, a second engine speed responsive pump, conduit means communicating said second pump and said pressure responsive means to open said variable orifice to decrease the resultant pressure in the conduit means for said first engine speed responsive pump as

engine speed increases, a diaphragm operatively connected to said adjustable fulcrum, spring means biasing said diaphragm and fulcrum to a position permitting said servo to increase the fuel output of said injector, and conduit means communicating manifold vacuum to said diaphragm permitting an increase in manifold vacuum to decrease the injector fuel output.

6. A fuel metering system as set forth in claim 5 in which said servo comprises a diaphragm, means operatively connecting said diaphragm and control member, and spring means biasing said diaphragm to decrease the fuel output of the injector means, said first pump conduit means communicating with said diaphragm enabling said first pump pressure to oppose the force of said spring means.

7. A fuel supply system for an internal combustion engine comprising a device for injecting a quantity of fuel to each engine cylinder during each combustion cycle, pressure responsive means operatively connected to said device to vary the quantity of fuel output per cycle, first means adapted to create a control pressure which is a function of engine speed, second means for modulating said control pressure in accordance with engine speed,

said second means reducing said control pressure in proportion to decreasing volumetric efficiency of the engine, and conduit means for conveying said reduced control pressure to said pressure responsive means.

8. A fuel supply system for an internal combustion engine comprising a device for injecting a quantity of fuel to each engine cylinder during each combustion cycle, pressure responsive means operatively connected to said device to vary the quantity of fuel output per cycle, first means adapted to create a control pressure which is a function of engine speed, second means for modulating said control pressure in accordance with engine speed, said second means reducing said control pressure in proportion to decreasing volumetric efficiency of the engine, conduit means for conveying said reduced control pressure to said pressure responsive means, and manifold vacuum responsive means for modifying the operation of said pressure responsive means causing an increase in manifold vacuum to decrease the fuel output of said injecting device for a given engine speed.

No references cited.

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,880,714 April 7, 1959

John B. Clark, Jr.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 4, line 9, after "communicating" strike out "with".

Signed and sealed this 8th day of September, 1959.

(SEAL)
Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents