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FUEL INJECTION SYSTEM

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FIG. 2-

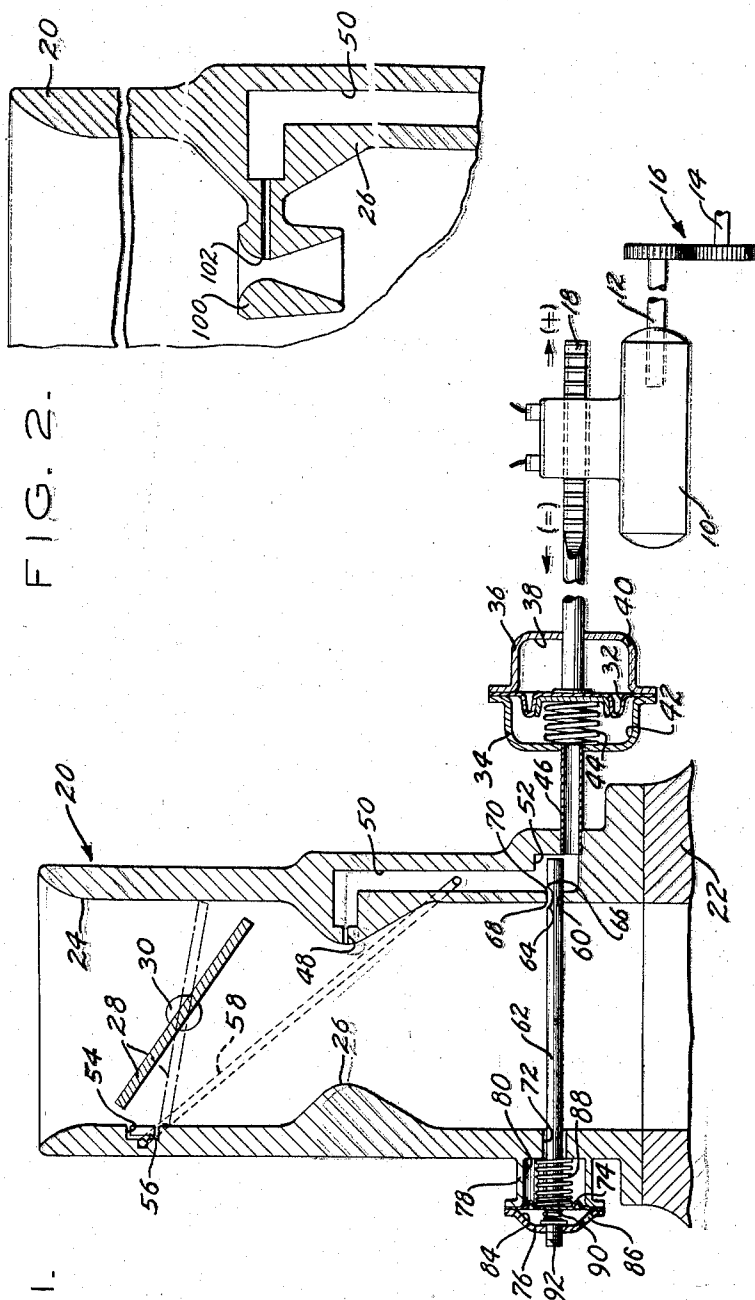


FIG. 1.

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FUEL INJECTION SYSTEM

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The present invention relates generally to a fuel injection system, and more particularly to a means for varying the fuel-air ratio in accordance with engine requirements.

It is an object of the present invention to provide a fuel supply system including a fuel pump and means including an air supply passage connected to the manifold of an internal combustion engine, the passage having a venturi and a flow control valve, and means responsive jointly to venturi depression, manifold vacuum, and valve position for controlling the delivery rate of said fuel pump.

It is a further object of the present invention to provide a fuel injection system for an internal combustion engine including a fuel pump operated at engine speed, an air supply passage connected to the intake manifold of the engine, the passage having a venturi and an air control valve therein, means responsive to venturi depression and manifold vacuum for controlling the fuel delivery per revolution of the pump, and means operable to eliminate the effect of manifold vacuum at either or both of its high and low limits.

It is a further object of the present invention to provide a fuel injection system as described in the preceding paragraph comprising means responsive to the position of the air valve for selectively modifying the operation of said pump.

More specifically, it is an object of the present invention to provide a fuel injection system for an internal combustion engine including a fuel pump adapted to be driven at engine speed, an air supply passage having a venturi and an air control valve therein, a vacuum operated motor for effecting adjustment of the fuel delivery per revolution of the fuel pump, and means for supplying operating vacuum to the motor comprising a first connection to the throat of the venturi, a second connection to the air supply passage in position to be upstream from the air valve when the air valve is closed and to be transferred to the downstream side of the air valve upon initial opening movement thereof, and a third passage to manifold vacuum including means responsive to manifold vacuum for restricting said passage when said manifold vacuum is above or below a predetermined intermediate range.

Other objects and features of the invention will become apparent as the description proceeds, especially when taken in conjunction with the accompanying drawings, illustrating preferred embodiments of the invention, wherein:

Figure 1 is a schematic sectional view of a fuel pump for a fuel injection system and control means therefor.

Figure 2 is a fragmentary sectional view of a modification of the structure shown in Figure 1.

In Figure 1 there is illustrated a fuel pump 10 having a drive shaft 12 connected thereto adapted to be driven from a rotating part of an internal combustion engine such for example as the cam shaft 14 thereof, the inter-

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connection between the shafts 12 and 14 being indicated by gearing 16. The pump 10 is of a known type and has means for adjusting the fuel delivery per revolution thereof. A pump of this type is disclosed in British Patent 414,954 of August 16, 1934 to which reference is made for details of a pump having the stated function. Accordingly, the details of the pump will not be described herein. It is sufficient to note however that adjustment of the output or delivery of fuel per revolution of the pump is accomplished by an adjusting member herein illustrated as a rack 18 movable longitudinally and engageable with a pinion carried by the pump. Movement of the rack 18 to the right as seen in Figure 1 results in an increase of fuel delivery per revolution of the shaft, and movement of the rack to the left results in a reduction in the fuel delivery per revolution. At this time it may be noted that since the pump is operated at a speed dependent on engine speed, fuel delivery is thus automatically proportioned to engine speed and thus tends generally to be properly related to the quantity of air drawn into the cylinders of the engine. However, under different operating conditions the fuel-air ratio requires modification and the system now to be described effects a control thereof adapted to produce a smooth engine performance curve.

The air intake comprises an exterior body 20 mounted on the intake manifold 22 of the internal combustion engine. The body 20 has an air passage 24 formed therein shaped to provide a venturi 26 intermediate its ends. Disposed above or upstream from the venturi 26 is an air valve or throttle 28 mounted on a shaft 30.

It will be understood that during engine operation when the air control valve 28 is in partially closed position, a pressure drop occurs across the valve 28 and the pressure below the valve assumes or is substantially equal to manifold pressure. Flow of air through the venturi however, causes pressure within the throat of the venturi to be depressed below the approximately equal values existing above and below the venturi. Pressure above the air valve 28 is approximately atmospheric or may be reduced somewhat therefrom by passage through an air cleaner or the like.

In order to effect automatic adjustment of the fuel pump 10 the rack 18 is connected to a flexible diaphragm 32 mounted within a housing formed by portions 34 and 36 between which the edges of the flexible diaphragm are clamped. To the right of the diaphragm, as seen in Figure 1, there is thus provided a chamber 38 which communicates with atmosphere through a port 40. To the left of the diaphragm 32 there is provided a chamber 42 containing a compression spring 44 urging the flexible diaphragm 32 to the right as seen in the figure. The chamber 42 communicates through a conduit 46 with a plurality of sources of reduced pressure or vacuum as will now be described.

Located at the throat of the venturi 26 is a restricted port 48 communicating with an enlarged passage 50 leading to a chamber 52 which is in communication with the conduit 46. Located upstream from the air valve 28 are ports 54 and 56 communicating with a passage 58 which leads to the previously described passage 50. It will be observed in Figure 1 that the ports 54 and 56 are located closely adjacent the upstream edge of the air valve 28 when the air valve is closed. However, when the air valve is given limited opening movement, its adjacent edge traverses the ports 54 and 56 and transfers these ports to the downstream side of the air passage where they then afford a connection to engine manifold vacuum. As the edge of the air valve 28 traverses the ports the lower port 56 is first placed in communication with manifold vacuum while the port 54 remains above the air valve. Accordingly, at this time the port 54 serves as an air

bleed and the transition from the closed position in which a pressure not substantially below atmospheric is supplied to the passage 58 to the position in which full manifold vacuum is supplied to the passage, is gradual.

Extending from the chamber 52 to the interior of the passage 24 is a port 60 in which is movable an elongated valve element 62. The valve element 62 is provided with a recess extending between the points designated 64 and 66 thereon. This recess cooperates with opposite sides 68 and 70 of the port 60. The arrangement is such that with the valve 62 in the position shown the port 60 is open because the edges 68 and 70 thereof are spaced inwardly from the ends 64 and 66 of the recess in the valve. Movement of the valve 62 in either direction from the illustrated position results in reduction of the valved area of the port 60.

The valve 62 extends through an enlarged opening 72 through the wall of the body 20 and is connected to a flexible diaphragm 74. A cover 76 is provided the edges of which clamp the edges of the flexible diaphragm 74 against the edge of a tubular housing portion 78 formed on the exterior of the body 20. There is thus provided a pressure chamber 80 communicating through the opening 72 to the interior of the air passage 24 at a point where manifold vacuum prevails. There is also provided a chamber 84 between the diaphragm 74 and the cover 76 which is connected by an open port 86 to atmosphere. Disposed in the chamber 80 is a compression spring 88 urging the valve 62 to the left.

Located in the chamber 84 is a compression spring 90 one end of which engages the flexible diaphragm 74. The other end of the spring 90 engages a threaded adjustable spring seat 92 carried by the cover 76. Thus, the effectiveness of the pair of springs 88 and 90 may be readily adjusted.

With the foregoing construction it is apparent that upon an increase in vacuum within the chamber 42 atmospheric pressure within the chamber 38 is effective to move the diaphragm 32 and hence the control rack 18 to the left in a direction to decrease the delivery of fuel per revolution of the shaft 12 and thus to lean out the fuel-air ratio. Conversely, a decrease in vacuum within the chamber 42 results in movement of the control rack 18 to the right, which in turn increases the delivery of fuel by the pump 10 per revolution of its shaft 12, thus increasing the richness of the fuel-air ratio.

Referring now to Figure 2 there is shown a slightly modified construction. In this case the body 20 in addition to having the venturi 26 provided therein also has a secondary venturi indicated generally at 100, the passage 50 being extended to the throat of the secondary venturi where it terminates in a port 102.

Operation

Movement of the rack 18 is dependent upon the combined effects of vacuum supplied to the chamber 42. The pressure within the chamber 42 is controlled primarily by the vacuum connection 58 to the ports 54 and 56. The effectiveness of this connection however, is modified by the bleed connection to venturi depression including the port 48 and the bleed connection to manifold vacuum at the port 60. With the valve 28 completely closed the ports 54 and 56 are subjected to a pressure not substantially below atmospheric pressure since at this time a minimum amount of air is flowing through the venturi, the venturi depression is negligible and the pressure at the port 48 is not substantially below manifold vacuum as existing at the port 60. However, when there is a substantial flow of air through the venturi, as will be the case when the valve 28 is partly open to expose ports 54 and 56 to manifold vacuum, the venturi depression existing at the port 48 will result in a vacuum at this port substantially below manifold vacuum as sensed at the ports 54 and 56 and at the port 60.

When the valve 28 is at or near the solid line position illustrated in Figure 1, the depression at port 54 and/or port 56 will be greater than the depression at the port 48, due to the venturi effect at the edge of the valve 38.

If the valve 28 is moved to closed position with the parts in the position illustrated by broken lines in Figure 1 the immediate effect of closure of the valve 28 is to expose the ports 54 and 56 to relatively high pressure which is communicated to the chamber 42. At the same time however, manifold vacuum increases since air flow past the valve 28 is substantially prevented. The relatively high manifold vacuum establishes a pressure differential across the diaphragm 74 which moves the valve 62 to the right partially or completely closing the valve port 60 and thus, reducing or eliminating the bleed action of this port. As a result of this the port 60 is ineffective to bleed air from the chamber 52 and the relatively high pressure at the ports 54 and 56 would prevail in the chamber 42 except for the venturi port 48. During the idle operation of the engine with the valve 28 closed, although venturi depression due to air flow through the valve is negligible, the manifold vacuum of the engine is present at the port 48 and accordingly, there is an air bleed somewhat reducing the effectiveness of the substantially atmospheric pressure supplied through the ports 54 and 56 to the chamber 42. The net result of the foregoing is that relatively high pressure is maintained within the chamber 42 and the rack 18 is shifted to the right, thus increasing the delivery of fuel per revolution of the drive shaft 12 of the pump 10. Thus, during idle operation a desirable rich fuel-air ratio is maintained.

When the air valve is open through a small angle the relatively high pressure existing in the air passage 24 above the valve 28 is cut off from the ports 54 and 56, and these ports are exposed to manifold vacuum. However, due to air flow past the valve 28, manifold vacuum decreases from the relatively high value at which it was maintained while the valve 28 was fully closed. This reduced manifold vacuum is transmitted through the passage 58 to the chamber 52. At this time the increased flow of air through the venturi results in substantially venturi depression and accordingly, a pressure exists at the port 48 which is depressed substantially below manifold vacuum. During this time manifold vacuum remains at a value sufficient to maintain the valve 62 in closing relation to the port 60. Accordingly, the pressure in the chamber 52 which is transmitted through the conduit 46 to the chamber 42 is in effect manifold vacuum as reduced by bleed through the port 48 to the throat of the venturi. This reduced pressure existing within the chamber 42 results in movement of the rack 18 to the left, thus decreasing the delivery of fuel from the pump 10 per revolution of its drive shaft 12, thereby decreasing the richness of the fuel-air ratio.

As the engine speed increases the flow of air through the venturi increases, the increase in manifold vacuum resulting in a decrease in bleed through the venturi port but the overall effect being an increase in vacuum as applied to the chamber 42. This in turn moves the rack 18 further to the left.

At some predetermined point, the flow of air through the venturi increases to a velocity which would normally cause the diaphragm 32 and the rack 18 to move too far to the left, causing the fuel-air ratio to become too lean. The valve 62 is so designed and adjusted that when this velocity is approached, the valve 62 will start to move to the left because of reduced manifold vacuum. This will result in partial opening of the valve 62, increasing the effect to manifold vacuum relative to manifold vacuum increased by the venturi depression available at the port 48, which will prevent excessive movement of the rack 18 to the left.

If it is assumed that the automobile is cruising with the valve 62 in a normal intermediate position, and the auto-

mobile is then accelerated, the air valve 28 will approach its wide open position, thereby reducing manifold vacuum to a low value. This low manifold vacuum permits the valve 62 to move to the left toward closed position. Accordingly, the pressure within the chamber 52 at this time is determined by the relative effectiveness of the ports 54 and 56 and the venturi port 48. The ports 54 and 56 are exposed to the negligible manifold vacuum, or in other words, are exposed to a pressure not substantially below atmospheric pressure. At this time the high velocity of air through the venturi results in substantial venturi depression but the actual value of the pressure at the venturi port is of course determined by manifold vacuum plus venturi depression. Accordingly, a relatively low vacuum exists within the chamber 52 and is communicated to the chamber 42 through the conduit 46. This results in movement of the diaphragm 32 and rack 18 to the right as required to produce the desirable enrichment of the fuel-air ratio required during acceleration.

The drawing and the foregoing specification constitute a description of the improved fuel injection system in such full, clear, concise and exact terms as to enable any person skilled in the art to practice the invention, the scope of which is indicated by the appended claims.

What I claim as my invention is:

1. A fuel-air ratio control system for a fuel injection system for an internal combustion engine having an intake manifold, a fuel pump having a drive shaft connected to said engine to be driven at a speed determined by engine speed and adapted to deliver its entire output to said engine, and an air supply passage having an air valve therein leading to said manifold, the control system comprising a pump control member movable to regulate the delivery of fuel per rotation of said pump shaft, a vacuum operated motor connected to said member, a venturi in said air passage downstream from said air valve, vacuum passage means connected to said motor having a first port in the throat of said venturi and a second port in communication with manifold vacuum, and a control valve for said second port operable to restrict said port when manifold vacuum is outside of an intermediate operating range.

2. A control system as defined in claim 1 in which said control valve has actuating means responsive to manifold vacuum connected thereto.

3. A control system as defined in claim 1 in which said control valve has actuating means responsive to manifold vacuum connected thereto, said actuating means being operable to close said second port when the manifold vacuum corresponds to engine idle operation.

4. A control system as defined in claim 1 in which said control valve has actuating means responsive to manifold vacuum connected thereto, said actuating means being operable to close said second port when the manifold vacuum corresponds to heavily loaded engine operation.

5. A fuel-air ratio control system for a fuel injection system for an internal combustion engine having an intake manifold, a fuel pump having a drive shaft connected to said engine to be driven at a speed determined by engine speed and adapted to deliver its entire output to said engine, and an air supply passage having an air valve therein leading to said manifold, the control system comprising a pump control member movable to regulate the delivery of fuel per rotation of said pump shaft, a vacuum operated motor connected to said member, a venturi in said air passage downstream from said air valve, vacuum passage means connected to said motor having a first port in the throat of said venturi and a second port in communication with manifold vacuum, a control valve for said second port operable to restrict said port when manifold vacuum is outside of an intermediate operating range, and a third port communicating with said air passage at a point upstream from an edge of said air valve in position to be traversed by said valve upon initial opening movement.

6. A control system as defined in claim 5 in which said control valve has actuating means responsive to manifold vacuum connected thereto.

7. A control system as defined in claim 5 in which said control valve has actuating means responsive to manifold vacuum connected thereto, said actuating means being operable to close said second port when the manifold vacuum corresponds to engine idle operation.

8. A control system as defined in claim 5 in which said control valve has actuating means responsive to manifold vacuum connected thereto, said actuating means being operable to close said second port when the manifold vacuum corresponds to heavily loaded engine operation.

9. Control means for a fuel pump for delivering fuel directly to an internal combustion engine having an air supply passage having an air valve and a venturi therein comprising a fluid motor including a vacuum chamber, passage means connecting said chamber to sources of reduced pressure comprising a port exposed at the inner surface of said air supply passage at the upstream side of an edge of said air supply valve when closed and in position to be traversed thereby on initial opening movement, and a restricted port in the throat of said venturi.

10. Control means for a fuel pump for delivering fuel directly to an internal combustion engine having an air supply passage having an air valve and a venturi therein comprising a fluid motor including a vacuum chamber, passage means connecting said chamber to sources of reduced pressure comprising a port exposed at the inner surface of said air supply passage at the upstream side of an edge of said air supply valve when closed and in position to be traversed thereby on initial opening movement, a restricted port in the throat of said venturi, a third port in communication with manifold vacuum within said air supply passage, and a regulating valve for restricting said third port when manifold vacuum is outside an intermediate operating range.

11. Control means as defined in claim 10 in which said third port comprises an opening through a wall of said air supply passage and said regulating valve comprises an elongated member movable longitudinally in said opening and having a reduced portion intermediate longitudinally spaced port closing portions.

12. Control means as defined in claim 11 in which said elongated member extends across said air supply passage through an opening provided in the wall portion thereof, a chamber surrounding said last opening communicating with manifold vacuum within said air supply passage and having a movable wall exposed on the outside of said chamber to atmospheric pressure, said member being operatively connected to said movable wall, and spring means urging said movable wall outwardly.

13. Control means for a fuel pump for delivering fuel directly to an internal combustion engine having an air supply passage having an air valve and a venturi therein comprising a fluid motor including a vacuum chamber, passage means connecting said chamber to substantially atmospheric pressure and manifold vacuum during engine idle operation and to a combination of manifold vacuum and venturi depressed manifold vacuum during normal operation.

14. Control means for a fuel pump having rotary drive means for delivering fuel directly to an internal combustion engine having a manifold, and an air supply passage provided with an air valve and a venturi downstream from said air valve connected to said manifold, said control means comprising vacuum responsive means operable when connected to a source of high vacuum to decrease the delivery of fuel per rotation of the pump drive means and to increase such delivery when connected to a source of a lower vacuum, means for applying a resultant of substantially atmospheric pressure and venturi vacuum when said air valve is closed, and a resultant of manifold vacuum and venturi vacuum when said air valve is moved to a partly open position.

15. Control means for a fuel pump having rotary drive means for delivering fuel directly to an internal combustion engine having a manifold, and an air supply passage provided with an air valve and a venturi downstream from said air valve connected to said manifold, said control means comprising vacuum responsive means operable when connected to a source of high vacuum to decrease the delivery of fuel per rotation of the pump drive means and to increase such delivery when connected to a source of lower vacuum, means for applying a resultant of substantially atmospheric pressure and venturi vacuum when said air valve is closed, and a resultant of manifold vacuum and venturi vacuum when said air valve is moved to a partly open position, and means for increasing the effect of manifold vacuum when said air valve is opened further.

16. Control means for a fuel pump having rotary drive means for delivering fuel directly to an internal combustion engine having a manifold, and an air supply passage provided with an air valve and a venturi downstream from said air valve connected to said manifold, said control means comprising vacuum responsive means operable when connected to a source of high vacuum to decrease the delivery of fuel per rotation of the pump drive means and to increase such delivery when connected to a source of a lower vacuum, means for applying a resultant of substantially atmospheric pressure and venturi vacuum when said air valve is closed, and a resultant of manifold vacuum and venturi vacuum when said air valve is moved to a partly open position, and means for increasing the effect of manifold vacuum when said air valve is opened further and for decreasing the effect of manifold vacuum when said air valve approaches wide open position.

17. Control means for a fuel pump having rotary drive means for delivering fuel directly to an internal combustion engine having a manifold, and an air supply passage provided with an air valve and a venturi downstream from said air valve connected to said manifold, said control means comprising vacuum responsive means operable when connected to a source of high vacuum to decrease the delivery of fuel per rotation of the pump drive means and to increase such delivery when connected to a source of a lower vacuum, means for applying a resultant of manifold vacuum and venturi vacuum during normal operation, and means for decreasing the effect of manifold vacuum when said air valve approaches wide open position.

18. A fuel injection system for an internal combustion engine having an air intake passage provided with an air valve, fuel supply means responsive primarily to engine speed for supplying fuel to the engine at a rate dependent primarily on engine speed, vacuum responsive means for modifying the rate of fuel supply comprising first means controlled by the position of said air valve for controlling the application of manifold vacuum to said vacuum responsive means, second means responsive to air flow to said engine for modifying the effect of manifold vacuum on said vacuum responsive means, and third means responsive to manifold vacuum for modifying the action of said first and second means.

19. A fuel injection system for an internal combustion engine having an air intake passage provided with an air valve and an air-flow metering venturi downstream from said air valve, fuel supply means responsive

primarily to engine speed for supplying fuel to the engine at a rate dependent primarily on engine speed, vacuum responsive means for modifying the rate of fuel supply comprising interconnected passage means connected to said vacuum responsive means comprising a first passage having a port exposed to a source of manifold vacuum and valve means responsive to manifold vacuum operable to close said port at high and low values of manifold vacuum, a second passage having a port exposed in said venturi to manifold vacuum as modified by air flow, and a third passage having a port controlled by the position of said air valve and adapted to connect said third passage to substantially atmospheric pressure when said air valve is closed.

20. A fuel injection system for an internal combustion engine having an air intake passage provided with an air valve and an air-flow metering venturi downstream from said air valve, fuel supply means responsive primarily to engine speed for supplying fuel to the engine at a rate dependent primarily on engine speed, vacuum responsive means for modifying the rate of fuel supply comprising interconnected passage means connected to said vacuum responsive means comprising a first passage having a port exposed to a source of manifold vacuum and valve means responsive to manifold vacuum operable to close said port at high and low values of manifold vacuum, a second passage having a port exposed in said venturi to manifold vacuum as modified by air flow, and a third passage having a port controlled by the position of said air valve and adapted to connect said third passage to substantially atmospheric pressure when said air valve is closed and to manifold vacuum when said air valve is at least partly open.

21. A fuel injection system for an internal combustion engine having an air intake passage provided with an air valve, fuel supply means responsive primarily to engine speed for supplying fuel to the engine at a rate dependent primarily on engine speed, vacuum responsive means for modifying the rate of fuel supply comprising means operable during normal engine operation to connect said vacuum responsive means to a source of manifold vacuum, means responsive to air flow to the engine to increase the effect of manifold vacuum on said vacuum responsive means, and means responsive to manifold vacuum for reducing the effect of manifold vacuum on said vacuum responsive means at very high and very low values of manifold vacuum.

22. In a control for a fuel injection system, means responsive to engine manifold vacuum for determining the rate of fuel flow to said engine, manual means for modifying the effect of manifold vacuum on said manifold responsive means, automatic means responsive to air flow to said engine for further modifying the effect of manifold vacuum on said first mentioned means, and additional means responsive to manifold vacuum for modifying the action of said manual means and said automatic means.

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