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[54] **VAPOR REGULATING VALVE**

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[51] **Int. Cl.** **F02d 19/00**

[58] **Field of Search** 123/136, 120

[56] **References Cited**

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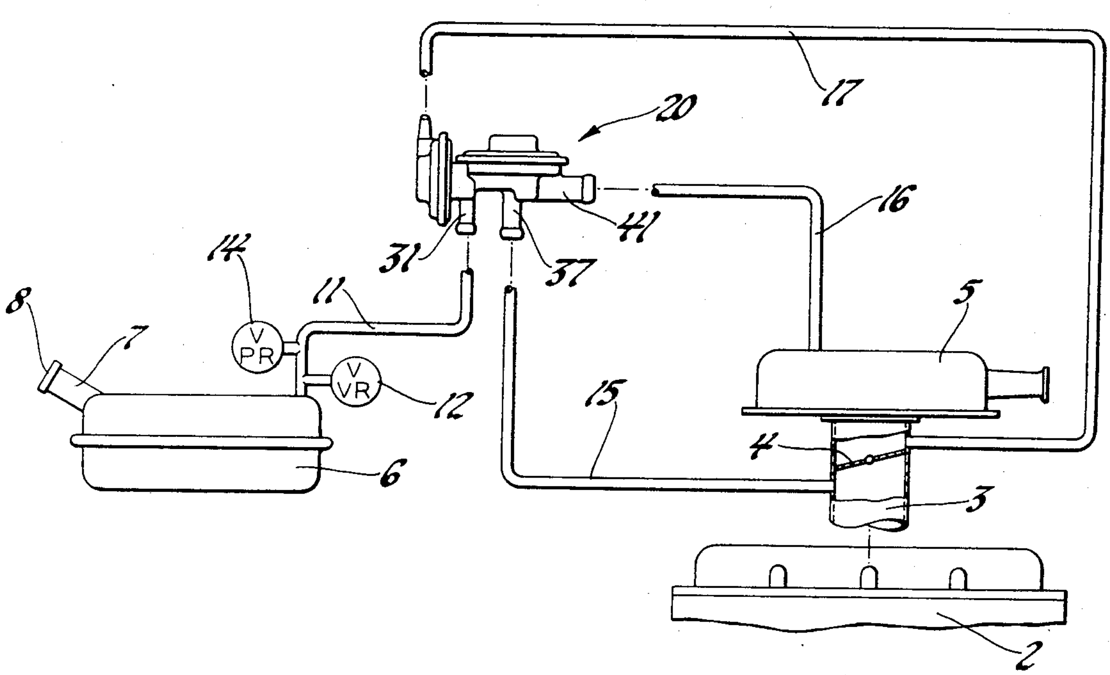
[57] **ABSTRACT**

A vapor regulating valve for use in a system for mixing air with fuel tank vapor stored in a fuel tank, the valve being constructed so that fuel tank vapor pressure applied against a diaphragm raises a metering valve to control the flow of fuel vapor and air to the intake manifold of an internal combustion engine. A second diaphragm responsive to engine intake manifold vacuum is used to effect the opening and closing of a valve to control the flow of fuel vapor as a function of engine operating conditions.

8 Claims, 2 Drawing Figures



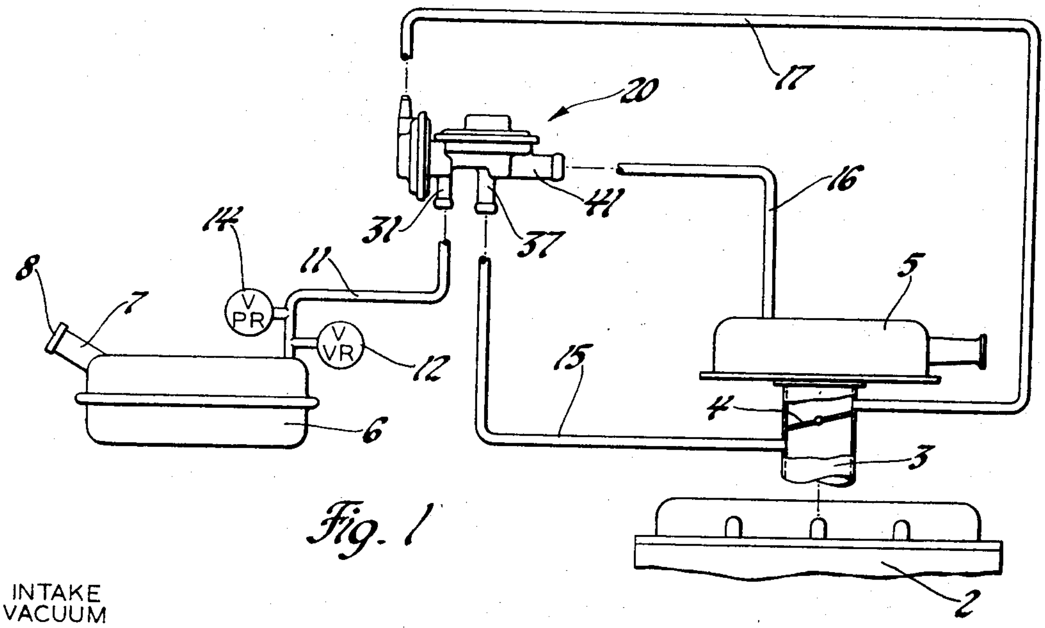


Fig. 1

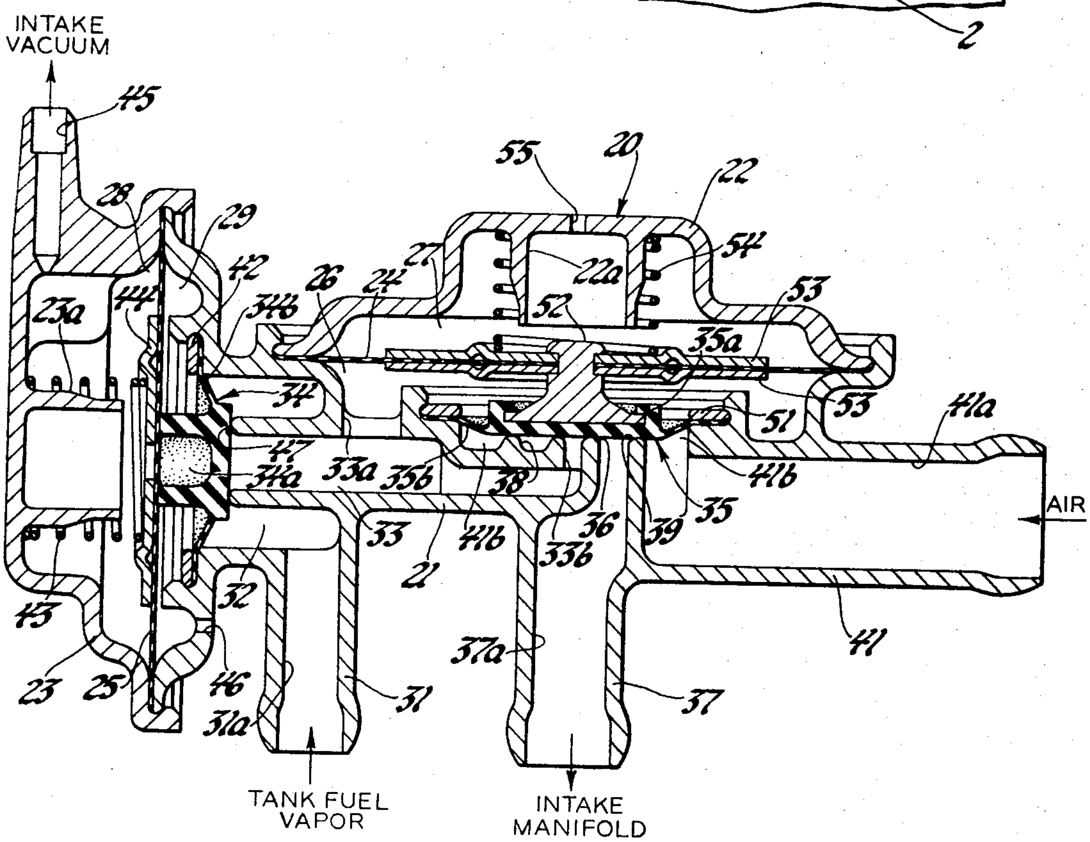


Fig. 2

VAPOR REGULATING VALVE

This invention relates to a vapor regulating valve and, in particular, to a vapor regulating valve for use in a system for mixing air with fuel tank vapor to regulate and control the flow of fuel vapor and air into the intake manifold of an internal combustion engine as a function of engine operation.

It is well known that vapors and gases emitted from internal combustion engines contribute to the present day problem of air pollution. Accordingly, much attention has been directed to controlling the polluting emissions from internal combustion engines. Many corrective devices have been proposed and utilized to control the most obvious source of emission, that is, the emission of fumes from the exhaust system and crankcase of the engine. Another source of hydrocarbon emission from an internal combustion engine is the fuel vapor escaping from the fuel system. In particular, gas vapor may escape from the external vents of both the fuel tank and the carburetor float bowl, either while driving or at rest. It has been estimated that of these uncontrolled fuel evaporation losses, the loss from the fuel tank accounts for from 50 percent to approximately 75 percent of this total.

In an effort to reduce the fuel vapor emission from the fuel system, various evaporative loss control device have been proposed and utilized whereby the fuel vapors are contained and then delivered to the intake manifold of the engine while it is in operation for consumption therein. This approach has worked successfully to help reduce the emission of fuel vapors directly from the fuel system but, under certain engine operating conditions, this feedback of the fuel vapors for consumption in the engine has effected engine operation or has increased the exhaust emission of unburned hydrocarbons, or both.

An improved system for mixing air with fuel tank vapors to overcome the above-identified problem is disclosed in copending United States Application Ser. No. 129,938 of Robert Seyfarth filed Mar. 31, 1971 and assigned to the same assignee as that of the subject application. In this system, a mixing valve having a fuel vapor pressure-controlled diaphragm-operated valve is used to meter fuel vapor and air into the intake manifold of the engine during operation of the engine.

It is therefore the principal object of this invention to improve a vapor regulating valve for use in a system for mixing air with fuel tank vapors whereby fuel tank vapor pressure applied against a diaphragm raises a metering valve to control the flow of fuel vapor and air to the intake manifold of an internal combustion engine, with second diaphragm operated valve means being provided to control the flow of fuel vapor as a function of engine operation.

Another object of this invention is to improve a vapor regulating valve for use in a system for mixing air with fuel tank vapors in which a first valve means is used to control the flow of fuel tank vapor to a second valve means which meters the flow of fuel vapor mixed with air to the intake manifold of an internal combustion engine.

A still further object of this invention is to improve a vapor regulating valve for controlling the loss of fuel vapor from a unit having a fuel reservoir and an internal combustion engine with an induction system whereby the flow of fuel vapor from the fuel reservoir

to the engine is controlled as a function of engine operating conditions and fuel vapor pressure.

These and other objects of the invention are attained by means of a vapor regulating valve for mixing air with fuel tank vapor for an internal combustion engine wherein the vapor regulating valve includes a first diaphragm which controls the operation of a first valve to control the flow of fuel vapor from a fuel tank to a second or metering valve actuated by a fuel vapor actuated diaphragm to meter the flow of a mixture of fuel vapor and air to the engine for combustion therein.

For a better understanding of the invention, as well as other objects and further features thereof, reference is had to the following detailed description of the invention to be read in connection with the accompanying drawings, wherein:

FIG. 1 is a schematic view of a portion of an engine fuel system incorporating a system utilizing a vapor regulating valve of the invention for mixing fuel tank vapors with air to the engine; and,

FIG. 2 is an enlarged sectional view of the vapor regulating valve of the system of FIG. 1.

Referring now to FIG. 1, an internal combustion engine 2 has an induction system including a carburetor intake manifold 3 thereon controlled by throttle valve 4, with an air cleaner 5 suitably mounted on the carburetor intake manifold. A supply of fuel, such as gasoline, for the engine 2 is contained in a fuel reservoir, such as fuel tank 6, from which liquid fuel is delivered through a suitable conduit and fuel pump, not shown, to the carburetor of the engine. Fuel tank 6, provided with a filler neck 7 closed by a non-vented cap 8, normally contains a quantity of liquid fuel with the space above the liquid fuel containing fuel vapor. A conduit 11 is connected to the fuel tank in position to receive fuel vapor from the tank and the conduit is provided with a vacuum relief valve 12 and a pressure relief valve 14, both set to open at predetermined pressures, as desired.

Fuel vapor from the fuel tank is delivered through the conduit 11 to the vapor regulating valve, generally designated 20, of the invention in a manner to be described whereby the fuel vapor is mixed with air and delivered by conduit 15 to the intake manifold 3 of the engine for combustion therein. Conduit 15 is connected to the intake manifold below the throttle valve 4. The vapor regulating valve 20 is connected in a suitable manner to a source of clean air and is herein shown, for the purpose of illustration only, as being connected by conduit 16 to the air cleaner 5. In addition, in order to control the operation of the vapor regulating valve 20 in relation to engine operating conditions, it is connected by conduit 17 to the intake manifold 3, just above the throttle valve 4 so that it is exposed to manifold vacuum when the engine is operating off idle, for a purpose to be described.

Referring now to FIG. 2, the vapor regulating valve 20 includes a valve housing 21 with top and side caps 22 and 23, respectively, which together make up a casing divided into four chambers by flexible diaphragms 24 and 25, each sealingly clamped at its outer periphery between the housing and the caps 22 and 23, respectively. The two chambers formed by the diaphragm 24 are a first or lower chamber 26 and a second or upper chamber 27, while the two chambers formed by diaphragm 25 are a third or vacuum left-side chamber

28 and a fourth or right-side chamber 29, as seen in FIG. 2.

The valve housing 21 is provided with a tube connection 31 for connection to conduit 11 for the entry of fuel vapor into the valve housing, the passage 31*a* in this tube connection being in communication with a generally horizontally disposed annular passage 32 which is concentric to a horizontally disposed passage 33 in the valve housing which is closed at one end, the left-hand end as seen in FIG. 2, by a valve 34. This passage 33 is connected by branch passage 33*a* to the lower chamber 26 and is closed at its other end by a metering valve 35 seating on the annular valve seat 36 encircling the reduced end 33*b* of this passage.

The valve housing 21 is also provided with a tube connection 37 for connection to the conduit 15 to supply a mixture of air and fuel vapor to the intake manifold 3 of the engine 2. The passage 37*a* through this tube connection terminates in an annular passage 38 defined between annular valve seat 36 and a second annular valve seat 39 for the valve 35. A third tube connection 41 on the valve housing 21 is adapted for connection to the conduit 16 for the admission of clean air. The passage 41*a* through this tube connection 41 is in communication with an annular passage 41*b* which, when the valve 35 is unseated, is in communication with passages 33 and 38 so that fuel vapor and air from these passages are mixed and delivered to the engine 2 via conduit 15 to the intake manifold 3.

The valve 34 made of suitable material, such as synthetic rubber, is in effect a diaphragm type valve with a central enlarged valve portion 34*a* and with a flexible annular portion 34*b* sealingly clamped at its outer periphery between the valve housing and a retaining ring 42 secured to the valve housing. The central portion of the valve 34 is provided on one side thereof with a flat surface portion to engage the valve seat 47 at the end of passage 33 and on its opposite side this central portion abuts against one side of diaphragm 25. The diaphragm 25 is normally biased so as to position valve 34 against valve seat 47 to close off the left-hand end of passage 33, as seen in FIG. 2, by means of a spring 43 abutting at one end against a diaphragm plate 44 on one side of the diaphragm, opposite valve 34, the left-hand side as seen in FIG. 2, and at its other end against an inside surface of cap 23, the spring 43 encircling an annular boss 23*a* extending inwardly of the cap 23. As previously described, the diaphragm 25 separates chamber 28 from chamber 29 with the chamber 28 being in communication through port 45 in the cap 23 and via conduit 17 with the intake manifold 3 on the upstream side of throttle valve 4. Chamber 29, which is actually formed by diaphragm 25, valve housing 21 and a second movable wall in the form of valve 34, is in communication with the atmosphere via port 46 in valve housing 21.

Metering valve 35, also made of a suitable material, such as synthetic rubber, is in effect a diaphragm type valve with a central valve portion 35*a* and a flexible annular portion 35*b* with portion 35*b* sealingly clamped at its outer periphery between the valve housing 21 and a retainer ring 51. As is apparent, metering valve 35 forms a second movable wall of the previously described lower chamber 26. The central body portion 35*a* of this valve is fixed to one end of a valve support 52 which is attached at its opposite end to the diaphragm 24 by means of a pair of diaphragm plates 53 positioned on opposite sides of the central portion of the diaphragm 24. The diaphragm 24 and therefore the valve 35 are normally biased downward, as seen in FIG. 2, to the valve closed position by means of a spring 54 abutting at one end against the uppermost diaphragm plate 53 and at its opposite end against the inside surface of the cap 22, the spring 54 encircling an annular boss 22*a* within the cap 22 and formed integral therewith. The diaphragm 24 and cap 22 form the upper chamber 27 which is vented to the atmosphere by means of port 55 in the cap 22.

In the vapor regulating valve described, the force of spring 43 and the relative working areas of diaphragm 25 and of valve 34 are chosen so that, for example, valve 34 is effective to seal fuel vapor from fuel tank 6 up to a fuel vapor pressure of 6 pounds per square inch, for example, while still permitting this unit to function in a manner to be described, on a low level vacuum signal of for example 2 inches of mercury. With this arrangement, valve 34 will thus remain closed when the engine is either off or running at idle so that fuel vapor is not admitted to the intake manifold during these periods of time. In a similar manner, the spring 54 and the effective working areas of diaphragm 24 and metering valve 35 can be chosen so that, for example, metering valve 35 is not unseated until fuel vapor pressure is greater than ½ pounds per square inch. It can also be seen that the effective working areas on opposite sides of metering valve 35 must also be taken into consideration, since when fuel vapor is admitted to passage 33 and lower chamber 26, the pressure of this fuel vapor is applied on opposite sides of this metering valve. By careful consideration of the above factors and proper sizing of the reduced end 33*b* of passage 33 and of annular passage 41*b* a proper fuel vapor and air mixture can be obtained with the valve 35 operating as a metering valve to control the flow of fuel vapor and air from these passages to the annular passage 38, passage 37*a* and then via conduit 15 to the engine 2.

The function of the vapor regulating valve under different modes of engine operation, that is, engine-off, engine running at idle position and engine off-idle, and at various fuel vapor pressures is as follows:

With the engine off or with the engine running at low idle speed, the positions of the valve 34 and of the metering valve 35 are as shown in FIG. 2 with these valves seated against their respective valve seats by the action of diaphragms 25 and 24, respectively, as biased by springs 43 and 54, respectively. In this position, the valve 34 blocks the flow of fuel vapor from the fuel tank 6 so that there is a complete fuel vapor shut-off up to a predetermined pressure as previously described. Pressure relief valve 14 on conduit 11 is used to prevent over-pressuring, as desired, of the fuel tank 6.

When the engine is running at an off-idle mode of operation, a sufficient vacuum, for example, 2 inches of mercury, is produced in the chamber 28 so that the higher atmospheric air pressure in chamber 29 acting on the opposite side of the diaphragm 25 from vacuum chamber 28 will overcome the biasing action of spring 43 to effect movement of the diaphragm to the left, as seen in FIG. 2. This movement of the diaphragm to the left now permits the fuel vapor pressure in passage 32, even though this fuel vapor pressure may be low, to effect movement of valve 34 to the left to unseat it from the valve seat 47 at the end of passage 33 so as to establish a flow path between passages 32 and 33. Fuel vapors can now enter passage **33** and via passage **33**a into the chamber **26** to operate against one side of diaphragm **24.** However, if the fuel vapor pressure is, for example, under ½ pounds per square inch, no fuel vapor will flow from the fuel tank **6** to the engine because this fuel vapor pressure acting against diaphragm **24** is insufficient to overcome the biasing action of spring **54** to permit unseating of the valve **35** from the seats **36** and **39.** At the same time, metering valve **35** will block the flow of air from conduit **16** through passages **41***a* and **41***b* into passage **37***a* to the engine.

With the engine running off-idle with vapor pressures of greater than, for example, ½ pounds per square inch in the fuel tank **6,** the vapor pressure will be sufficient to move diaphragm **24** upward, as seen in FIG. **2,** to unseat metering valve **35** from seats **36** and **39** to now allow air entering through passage **41** to mix with the fuel vapors entering through passage **33** and permit this mixture of air and fuel vapors to be discharged through passage **37***a* and via conduit **15** to the intake manifold **3** of the engine. Fuel vapors will thus flow to the engine until such time as the fuel vapor pressure drops below a predetermined value, for example, below ½ pounds per square inch, at which time the diaphragm **24** can again move downward by the biasing action of spring **54,** to the position shown in FIG. **2,** to effect seating of metering valve **35** against the valve seats **36** and **39** to cut off further fuel vapor flow from the fuel tank **6** via conduit **11** and air flow from conduit **16** to the engine or until the engine is running at low idle or is at engine-off at which time the vacuum in chamber **28** is reduced sufficiently to allow spring **43** to bias diaphragm **25** against valve **34** to shut-off flow of fuel vapor from passage **32** to passage **33.**

What is claimed is:

1. In a vapor recovery system for an internal combustion engine having an induction system and a fuel reservoir, a vapor regulating valve including a housing having an inlet means connectable to the fuel reservoir for receiving fuel vapor discharge from the fuel reservoir, an air inlet means, and an outlet means connected to the induction system for delivering a mixture of fuel vapor and air to the induction system, a valve mechanism disposed between said outlet means and said inlet means and said air inlet means for controlling the flow of fuel vapor and air from both said inlet means to said outlet means, spring means biasing said valve mechanism to prevent flow of fuel vapor and air from said inlet means to said outlet means and pressure means responsive to the pressure in said fuel reservoir and connected to said valve mechanism whereby said first valve mechanism is operated to control the rate of flow of fuel vapor and air from said inlet means to said outlet means in accordance with the pressure of the fuel vapor in said fuel reservoir, a diaphragm valve disposed between said inlet means and said valve mechanism for controlling the flow of fuel vapor to said outlet means as controlled by said first valve mechanism, second spring means biasing said diaphragm valve to shut off fuel vapor flow from said inlet means and means responsive to the pressure in said induction system and operatively connected to said diaphragm valve whereby said diaphragm valve is operated to control the flow of fuel vapor from said inlet means toward said outlet means in accordance with the vacuum pressure in the induction system as affected by the operating conditions of the internal combustion engine.

2. A vapor regulating valve for use in a fuel vapor recovery system for an internal combustion engine having an intake manifold and a fuel reservoir, said vapor regulating valve including a valve housing having a first passage means therein including a first inlet for fuel vapor connectable to the fuel reservoir, a second passage means including an air inlet connectable with a source of atmospheric air and a third passage means therein including an outlet connectable to the intake manifold of the engine, a first valve movable in said first passage means between an open position and a closed position, first valve operating means including a pressure responsive diaphragm in said housing to form first and second chambers on opposite sides of said diaphragm with said diaphragm being positioned to engage said first valve whereby said first valve may be closed by actuating said diaphragm, said first chamber being connectable to the intake manifold and said second chamber being open to the atmosphere, a second valve positioned in said housing and movable between an open position and a closed position to control the flow from said first passage means and said second passage means to said third passage means, second valve operating means including a second pressure responsive diaphragm in said housing to form a chamber therein in communication with said first passage means between said first valve and said second valve and means operatively connecting said second diaphragm and said second valve whereby said second valve is positioned by said diaphragm.

3. A vapor regulating valve according to claim **2** wherein a first spring means is positioned in said first chamber in operative relation to said first diaphragm to normally bias said first valve to said closed position.

4. A vapor regulating valve according to claim **3** wherein said first valve is a diaphragm type valve with a portion of one side thereof in communication with said first inlet and responsive to fuel vapor pressure in the fuel reservoir to effect movement of said first valve to said open position.

5. A vapor regulating valve according to claim **2** including a second spring means in said housing positioned in operative relation to said second diaphragm to normally bias said second valve to said closed position.

6. A vapor regulating valve for controlling the loss of fuel vapor from a unit having a fuel reservoir and an internal combustion engine with an induction system, said vapor regulating valve including a housing means having a fuel vapor inlet means connectable to the fuel reservoir for receiving fuel vapor discharge from the fuel reservoir, an air inlet means, an outlet means connectable to the induction system for delivering a mixture of fuel vapor and air to the induction system, a first valve mechanism disposed between said outlet means and said fuel vapor inlet means and said air inlet means for controlling the flow of fuel vapor and air from both said inlet means to said outlet means, spring means biasing said valve mechanism to prevent flow of fuel vapor and air from said inlet means to said outlet means, differential pressure actuated means responsive to the pressure in the fuel reservoir and connected to said first valve mechanism whereby said first valve mechanism is operated to control the rate of flow of fuel vapor and air from said inlet means to said outlet means in accordance with the pressure of the fuel vapor in said fuel reservoir, a second valve mechanism disposed between said fuel vapor inlet means and said first valve mechanism and said pressure actuated means for controlling flow of fuel vapor to said outlet means as controlled by said first valve mechanism and to said pressure actuated means, second spring means biasing said second valve mechanism to shut off fuel vapor flow from said fuel vapor inlet means and second differential pressure actuated means responsive to the pressure in the induction system and operatively connected to said second valve mechanism whereby said second valve mechanism is operated to control the flow of fuel vapor from said fuel vapor inlet means in accordance with the operating conditions of the internal combustion engine.

7. A vapor regulating valve according to claim 6 wherein said differential pressure actuated means is a diaphragm and wherein said diaphragm and the baising force of said spring means are sized so as to prevent opening of said first valve means below a predetermined pressure of fuel vapor in said fuel reservoir.

8. A vapor regulating valve according to claim 6 wherein said second differential pressure actuated means is a diaphragm and wherein said diaphragm and the biasing force of said second spring means are sized so as to keep said second valve mechanism closed to prevent fuel vapor flow from said fuel vapor inlet means when said internal combustion engine is off or running at low idle speed.

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