Aug. 7, 1962 J. B. GREGORY ET AL 3,048,157

AIR POLLUTION ABATEMENT SYSTEM

Filed June 30, 1959

2 Sheets-Sheet 1

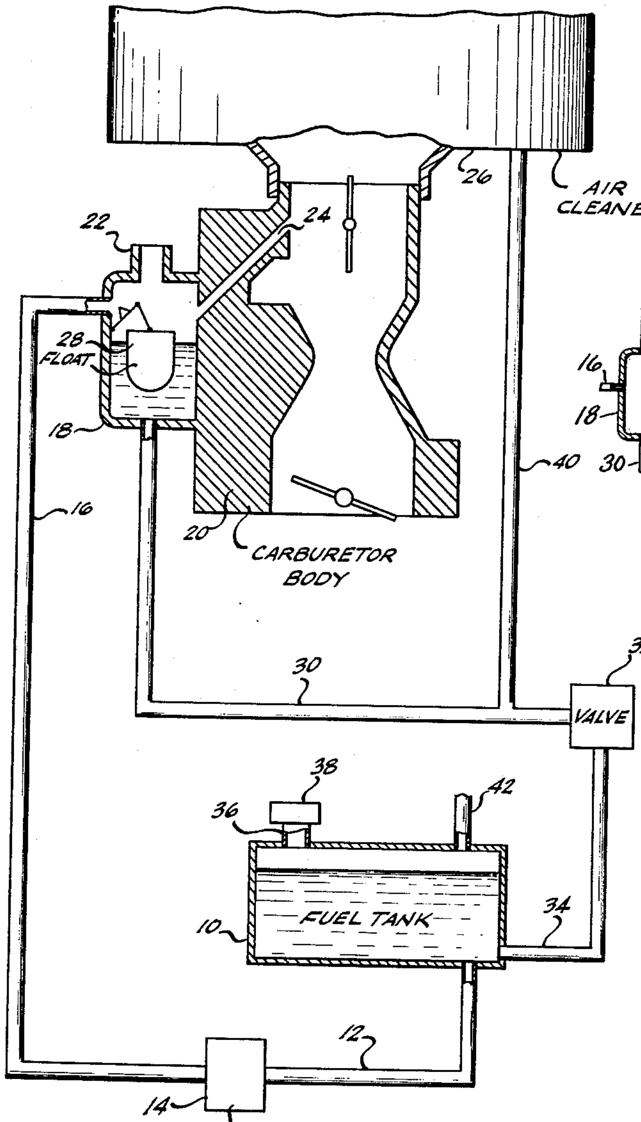

FIG. 1

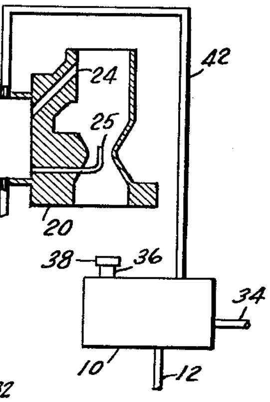

FIG. 3

INVENTORS
JAMES B. GREGORY
HOWARD D. EMERSON
CHARLES C. MOORE

BY Lannas S. Henderson

AGENT

Aug. 7, 1962 J. B. GREGORY ET AL 3,048,157

AIR POLLUTION ABATEMENT SYSTEM

Filed June 30, 1959 2 Sheets-Sheet 2

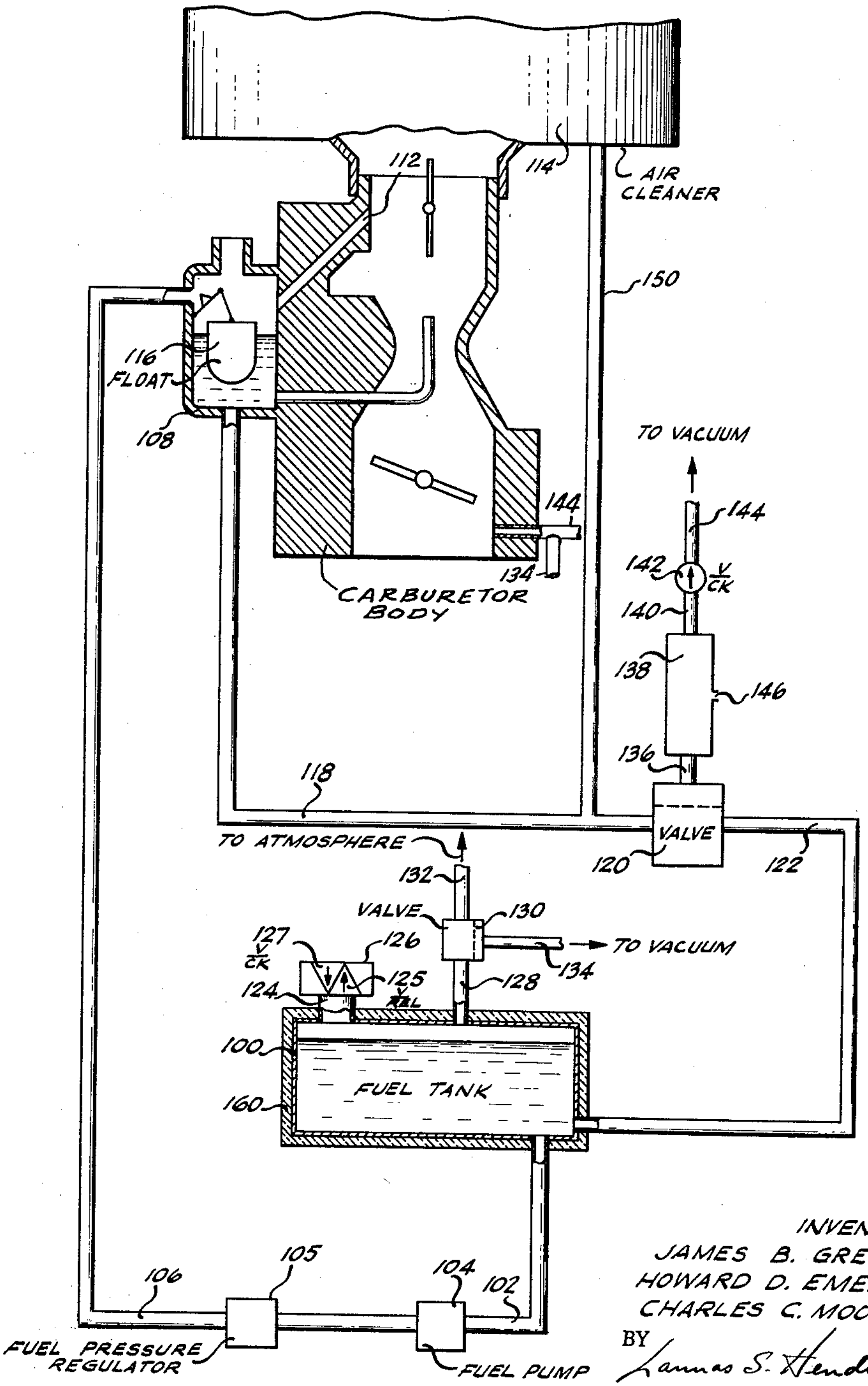

FIG. 2

INVENTORS
JAMES B. GREGORY
HOWARD D. EMERSON
CHARLES C. MOORE
BY Lannas S. Henderson
AGENT

United States Patent Office

3,048,157

Patented Aug. 7, 1962

3,048,157

AIR POLLUTION ABATEMENT SYSTEM

James B. Gregory, Charles C. Moore, and Howard D. Emerson, Fullerton, Calif., assignors to Union Oil Company of California, Los Angeles, Calif., a corporation of California

Filed June 30, 1959, Ser. No. 823,914

25 Claims. (Cl. 123—136)

This invention relates to the abatement of air pollution, and in particular concerns certain new and useful improvements in fuel systems for internal combustion engines, such as those employed for the propulsion of motor vehicles.

The operation of motor vehicles contributes markedly to the air pollution problem in large cities by the release of hydrocarbons to the atmosphere, either as unburned fuel via the exhaust system, or as evaporated fuel via the fuel supply system. A great deal of evaporated fuel originates from the motor vehicle engine carburetor, both during periods of operation and non-operation. One of the major sources of these carburetor evaporation losses is from the carburetor float bowl, which is a vented reservoir of volatile fuel constantly exposed to heat from both the atmosphere and the engine. These evaporative losses are essentially a function of fuel volatility, float bowl temperature, and carburetor design.

Fuel vapors from the conventional float bowl can escape to the atmosphere along two principal routes: (1) directly to the atmosphere through external vents in the float bowl, and (2) through so-called internal vents or balancing tubes into the body of the carburetor. When the engine is running, hydrocarbon vapors escaping through the internal vents are drawn into the combustion chamber with incoming air and subsequently combusted. However, any vapors that escape through the external vents during this operational period will contaminate the atmosphere. When the engine is turned off, hydrocarbon vapors escape through both the internal and external vents to the atmosphere. However, since carburetors perform at widely varying temperatures with volatile fuels, some form of venting must be used to keep the float bowl at essentially the same pressure as the other communicating carburetor chambers when the engine is running.

One major cause of carburetor evaporation loss, only casually considered by previous investigators, is the so-called carburetor "hot soak" which begins immediately after the engine is turned off. Heat stored by the engine while running is transmitted to the carburetor float bowl, which, depending on design, normally contains from around 80 to 200 ml. of volatile hydrocarbon fuel. As the trapped fuel in the float bowl is heated, evaporation occurs through the aforementioned carburetor vents. Generally, there is a float bowl temperature rise of from about 40 to 60° F. from the bowl temperature at the time the engine is shut off to the peak temperature reached (usually in about 20 to 40 minutes) during the "hot soak" period. It can be generally stated that atmospheric temperatures have little effect upon the "hot soak" temperature of the carburetor bowl; the bowl temperature seems to be controlled primarily by engine coolant temperature. Carburetor design has virtually no effect on "hot soak" losses, except in the matter of float bowl fuel capacity. It has been found that normal losses to the atmosphere from the carburetor float bowl during the "hot soak" period range from 10 to 30 percent of the fuel remaining in the float bowl at the time the engine is stopped.

It is accordingly an object of this invention to provide an improved method and apparatus for the abatement of atmospheric pollution resulting from the operation of internal combustion engines.

Another object is to provide an improved method and apparatus for effecting a substantial reduction in the gross fuel consumption of automobiles, thus resulting in more efficient and economic operation.

A further object is to substantially reduce the evaporative fuel losses from the fuel supply system of internal combustion engines.

Other and related objects will be apparent from the following detailed description of the invention, and various advantages not specifically referred to herein will be apparent to those skilled in the art on employment of the invention in practice.

We have now found that the foregoing objects and their attendant advantages can be realized in a conventional internal combustion engine, such as is used in the propulsion of motor vehicles, by providing the float bowl of a conventional carburetor with a fuel drain line which returns the fuel remaining in the carburetor float bowl to the storage tank as soon as the engine is stopped. This removes the highly volatile hydrocarbons from the high temperature environment of the carburetor float bowl before any significant losses from "hot soak" can occur, thus eliminating a major source of air pollution.

The invention will be more readily understood by reference to the accompanying drawings which form a part of this application. FIGURE 1 is a schematic diagram of one of the simplest embodiments of this invention. FIGURE 2 is a schematic diagram of the apparatus of this invention in one of its preferred embodiments. FIGURE 3 is a modification of the apparatus of FIGURE 1 wherein the fuel storage tank vent is connected to the vapor space of the carburetor fuel reservoir chamber. It is to be understood that although the float bowl draining method and apparatus of this invention is broadly applicable to any internal combustion engine using a volatile fuel and a fuel induction system, it is particularly useful for gasoline-burning engines, such as those used in automobiles, trucks, buses and the like.

Referring now more particularly to FIGURE 1, the apparatus there shown consists essentially of the fuel supply system for an internal combustion engine. The fuel supply enters fuel tank **10** via inlet conduit **36**. When fuel tank **10** has an adequate supply of volatile fuel, tank cap **38** seals inlet conduit **36**. Tank vent **42** communicates with the atmosphere and, as is conventional with fuel storage tanks on motor vehicles, maintains fuel tank **10** at atmospheric pressure. Fuel is supplied to carburetor float bowl **18** via line **12**, fuel pump **14**, and line **16**. Fuel pump **14** can be any of the conventional pumps used in the fuel supply systems of internal combustion engines such as a vacuum-operated fuel pump, an electric fuel pump, a mechanical pump, or the like. The fuel enters carburetor float bowl **18** at a rate controlled by the characteristics of the fuel pump **14** and float valve **28** which, as it rises, restricts the outlet of line **16** into carburetor float bowl **18**, thus acting as a liquid level control device to maintain a substantially constant level of fuel within carburetor float bowl **18**.

The foregoing constitute conventional elements found in nearly all carburetor fuel supply systems. According to our invention, a novel fuel return system is provided in the form of a return line **30**, opening from the bottom of bowl **18**, and communicating in fuel delivery relationship with fuel tank **10** via drain valve **32** and line **34**. Valve **32** can be located at any intermediate horizontal level between the inlet to line **30** and the outlet of line **34**, but for convenience of access is preferably located immediately below the carburetor body **20**. Return lines **30** and **34** can be constructed of ⅛ or ¼ inch I.D. tubing, such as is used for conventional fuel delivery lines. However, as will be more fully explained below, a suitable restriction to flow is incorporated into the fuel return system so that fuel from bowl **18** will not be returned to tank **10** at a faster rate than the supply system can deliver fuel to bowl **18**.

One method of operating the apparatus as shown in FIGURE 1 is to have drain valve **32** in a blocked open position. There is then a constantly open drain line from float bowl **18** to fuel tank **10**, both when the engine is operating and when the engine is stopped. With drain valve **32** blocked open and the engine running, fuel is continuously pumped from fuel tank **10** via fuel pump **14** to float bowl **18**. Simultaneously, fuel is constantly flowing from float bowl **18** to fuel tank **10** via line **30**, blocked open drain valve **32**, and line **34**. Thus, there is a constantly circulating flow of fuel from fuel tank **10** to carburetor float bowl **18** and back to fuel tank **10**, with an adequate reservoir level in carburetor float bowl **18** being maintained by float valve **28**. The drainage capacity of the fuel return system comprising line **30**, valve **32**, and line **34** is such that the flow through this return system is small compared to the total capacity of the fuel supply system. Typically, the rate of gravity flow through the return system is about $\frac{1}{50}$ to $\frac{1}{2}$ of the flow capacity of the fuel supply system to the carburetor.

At no time during engine operation can there be allowed an excessive float bowl drainage so that the reservoir will be depleted to an inoperable point or to a level which will detrimentally affect normal operation. This drainage or return flow can be adjusted to the desired level by manipulation of drain valve **32**. Alternatively, drain valve **32** can be replaced by an appropriate orifice which will restrict return flow so as to maintain an adequate fuel supply in carburetor float bowl **18** during all conditions of engine operation. A restriction such as an orifice, or the partial closing of drain valve **32**, can occasionally be needed to prevent reverse surge in the drain line from the fuel tank during downhill driving or rapid stops, resulting in overfilling of carburetor bowl **18**.

When the engine is stopped, fuel pump **14** no longer delivers fuel, as it is controlled by the engine operation. Carburetor float bowl **18** is then quickly emptied of fuel via line **30**, drain valve **32**, and line **34**. Thus, with the above-described mode of operation there is little fuel loss through external vent **22** to the atmosphere, since the highly volatile fuel has been removed from the carburetor float bowl within a few seconds to 3 or 4 minutes after the engine is stopped. When operation of the car is resumer fuel pump **14** quickly introduces fuel as hereinbefore described to carburetor float bowl **18** thus restoring the fuel therein to an adequate level for engine operation.

Line **34** can enter fuel tank **10** either in the vapor space at the top of the fuel tank or, in the preferred embodiment as shown in FIGURE 1, the drained fuel from carburetor float bowl **18** can return to the bottom of fuel tank **10**. Since this drainage fuel is usually warmer than the fuel in the fuel tank because of passing through the carburetor and the engine compartment, the preferred embodiment reduces evaporative fuel flashing by introducing said drainage fuel into the bottom of the cool body of fuel in tank **10**.

Further modifications of the apparatus which have been highly successful in reducing evaporation loss, particularly during engine operation, involve the closing of external vent **22** by means of a plug or some other appropriate vapor-tight closure. A large variety of conventional carburetors have been operated with plugged external vents for extended periods of time in combination with the method and apparatus of our invention with a high degree of success. Evaporation losses from the fuel system were materially reduced, with a resultant reduction in atmospheric pollution and in gross fuel consumption. It has been found that as a further means of reducing evaporative losses of volatile fuels, fuel tank **10** should be insulated to reduce the acquisition of heat, thus lowering the temperature of the fuel contained therein. By means of tank insulation there is a reduced temperature rise during motor vehicle operation, which thus reduces the vapor pressure of the fuel and effectively reduces the evaporation losses from the fuel tank itself, through tank vent **42**. Any conventional insulating material can be used such as glasswool, asbestos, and the like.

Referring now more particularly to FIGURE 3, the apparatus here shown is a fragmentary view of the fuel supply system of FIGURE 1 with a modified fuel tank venting apparatus therein. The apparatus of FIGURE 3 is identical in every respect to FIGURE 1 except for the direct connecting of tank vent **42** of fuel tank **10** to external vent **22** of float bowl **18**. Thus, there is communication between the vapor space of fuel tank **10** and the vapor space of float bowl **18** which, during engine operation, will permit any vapors evaporating from fuel tank **10** to pass through tank vent **42** to float bowl **18** and thence through internal vent **24** to the throat of the carburetor where these vapors are swept into the engine combustion chamber and burned. When the engine is stopped the same vapor path is provided which maintains float bowl **18** and fuel tank **10** at substantially the same pressure thus permitting easy draining of float bowl **18**.

Return lines **30** and **34**, under certain design conditions, i.e., when said lines are not in continuous descent to fuel tank **10**, and/or do not have sufficient size to relieve themselves of the gas or vapor which occupies this line space after the carburetor bowl has drained, can become "vapor locked" after drainage. To relieve this problem, we may provide one or more atmospheric vents which, when engine operation is resumed, serve to release trapped vapors thus priming the lines for satisfactory operation. Vent line **40** is such a conduit for venting the drain-back system. As shown in FIGURE 1, vent **40** can be returned to the air cleaner assembly to prevent the escape of volatile fuel vapors into the atmosphere during engine operation, or it can be vented directly to the atmosphere if desired. The location of vent **40** in the fuel drain-back conduit is not critical as long as it allows gas to escape from the conduit for effective draining. The outlet of any such vents should preferably be located above the level of the fuel in float bowl **18**.

An alternate method of operation of the apparatus shown in FIGURE 1 comprises starting the engine operation with drain valve **32** closed and carburetor float bowl **18** empty. Fuel is supplied to carburetor float bowl **18** as hreinbefore described, which fills and maintains an adequate fuel reservoir through the action of float valve **28**. There is no flow of gasoline through the system shown by line **30**, drain valve **32** and line **34** during engine operation. When the engine is stopped, fuel pump **14** stops and therefore no longer supplies fuel via line **16** to carburetor float bowl **18**. Drain valve **32** is immediately opened upon engine stoppage and float bowl **18** is drained of its fuel content via line **30**, drain valve **32** and line **34** to fuel tank **10**. Drain valve **32** is then closed prior to or coincident with resumption of engine operation. The opening and closing of drain valve **32** can be effected by the engine intake manifold vacuum if it is a vacuum actuated valve, or by the ignition switch if a solenoid actuated valve, or manually if a conventional mechanical valve. The opening and closing of such valves is conventional and well-known in the art and hence need not be described in detail.

Referring now more particularly to FIGURE 2, the apparatus here shown comprises a preferred embodiment of our fuel supply system. The volatile hydrocarbon fuel enters fuel tank **100** via inlet conduit **124**. The outer surface of fuel tank **100** is covered with about one inch of glasswool insulation **160**. When fuel tank **100** is filled to the desired level, tank cap **126** seals inlet conduit **124**. Tank cap **126** is a conventional pressure relief cap which maintains the fuel tank under a positive pressure between about 0 and about 2 p.s.i.g. The design of these so-called pressure caps is such that when the pressure within the fuel tank falls below atmospheric, a check valve **127** in the fuel cap opens so that it is impossible for vacuum to develop within fuel tank **100**. When pressures above about 2 p.s.i.g. develop, a relief valve **125** is opened to reduce the pressure to about 2 p.s.i.g. The fuel from tank **100** is supplied to carburetor float bowl **108** via line **102**, fuel pump **104**, fuel pressure regulator **105**, and line **106**. Fuel pump **104** in this preferred embodiment is an electrically operated pump which operates whenever the ignition is on and ceases operation, thus blocking the passage of fuel, when the ignition is off. Fuel pump **104**, however, could be a conventional vacuum-operated fuel pump or a mechanical pump or the like. Conventional fuel pressure regulator **105** is an optional element of the fuel system whose use is dictated by the fuel pump used, the operating pressure of the fuel tank, and similar considerations. Normally these pressure regulators operate at between about 1 p.s.i.g. and about 5 p.s.i.g. fuel pressure to the carburetor. The fuel enters carburetor float bowl **108** from line **106** at a rate controlled by the pressure setting of fuel pressure regulator **105** and conventional float valve **116** which, as the fuel within float bowl **108** rises, restricts the entrance of line **106** into float bowl **108** and thus acts as a metering device to maintain a substantially constant level of fuel within carburetor float bowl **108**.

The fuel drain-back system comprises a tubular line **118** opening from the bottom of float bowl **108**, vacuum operated drain valve **120**, and line **122** which opens into fuel tank **100**. Fuel tank **100** is in communication with the atmosphere via line **128**, vacuum operated vent valve **130** and conduit **132**. The operation of valve **120** in the fuel drain-back system is controlled by a vacuum delay system comprising conduit **136**, a small vacuum reservoir tank **138**, conduit **140**, check valve **142**, and vacuum supply conduit **144**.

The operation of the fuel supply system of this preferred embodiment starts with the initial filling through inlet conduit **124** of fuel tank **100** until the desired fuel level is obtained. Pressure cap **126** is then secured thus sealing the end of inlet conduit **124**. Prior to starting the internal combustion engine of which this fuel supply system is a part, valve **130** is open and valve **120** is open. When the engine is started the vacuum actuated valves **120** and **130** close, and fuel is supplied to carburetor float bowl **108** via line **102**, fuel pump **104**, fuel pressure regulator **105**, and line **106**. Float bowl **108** is quickly filled to the operative level as controlled by float valve **116**. During the period of engine operation, valve **120** and **130** remain closed. Keeping valve **130** closed prevents the escape of fuel vapors from the tank vent line **132** to the atmosphere, which, due to the slopping of the fuel within the tank can be an appreciable source of hydrocarbon contaminant in the atmosphere. During engine operation any vapors which develop in float bowl **108** travel via internal vent **112** to the other carburetor chambers and are thus swept into the combustion chambers of the engine and burned.

When the engine is shut off, the conventional vacuum manifold of the internal combustion engine returns to atmospheric pressure, thus dissipating the vacuum source which was holding valves **120** and **130** closed, and valve **130** opens immediately allowing tank **100** to come to atmospheric pressure. The opening of valve **120**, however, is delayed by the action of vacuum reservoir tank **138**. In a fuel system as herein described, it is necessary that tank **100** be near or at the same pressure as float bowl **108** when drain valve **120** is opened. Otherwise, there could be a reverse surge of fuel into float bowl **108** which would prevent proper drainage, and might even overflow into the engine compartment resulting in excessive hydrocarbon loss to the atmosphere. When the engine vacuum manifold returns to atmospheric pressure, check valve **142** automatically closes thus allowing vacuum reservoir tank **138** to come gradually to atmospheric pressure by the entrance of air through orifice **146**. The delay in opening valve **120** is thus a function of the size of orifice **146** and vacuum reservoir tank **138**. A typical system has a time delay of about 15 seconds, and comprises a vacuum reservoir volume of about 32 cubic inches and an orifice diameter of about 0.02 inch. Obviously, however, any other combination of orifice size and vacuum reservoir volume which would give the desired time delay could be used. Operative time delay periods of about 3 to 60 seconds are contemplated.

When the pressure in vacuum reservoir tank **138** approaches atmospheric, valve **120** opens and permits the fuel remaining in carburetor float bowl **108** to drain back to fuel tank **100** via line **118**, opened drain valve **120**, and line **122**. Line **122** is supplied with an optional atmospheric vent **150** to air cleaner **114**, which, as previously discussed with respect to FIGURE 1, allows the escape of trapped air and vapors in the drain-back conduit system thus allowing effective draining. When the engine is restarted, valves **120** and **130** close by action of the engine vacuum source, and the system repeats the first described mode of operation.

The fuel system as above described is not limited to the use of vacuum actuated valves. Valves **120** and **130** can be electrical solenoid valves with appropriate circuiting usually in conjunction with the ignition circuit. Thus, valves **120** and **130** would be in the open position when the ignition was off and in the closed position when the ignition was turned on. Instead of the vacuum delay system used to control valve **120**, we may also use a conventional mechanical or electrical delay system. Valves **120** and **130** may also be mechanical valves operated manually. Although the fuel systems shown in FIGURES 1 and 2 are illustrated with a single bowl carburetor, the method and apparatus of our invention have been successfully applied to an engine having a two-bowl carburetor, and any number of carburetors or bowls may be integrated into the system.

The air pollution abatement device of this invention is rugged by virtue of its simplicity, but should any maintenance or repair work be required, this can easily be accomplished since conventional parts, fittings, and equipment are used throughout.

While in the foregoing description, we have referred mainly to carburetor fuel induction systems, the invention in its broadest aspect is not limited thereto. Other fuel induction devices, such as pressure injectors may also draw from small intermediate fuel reservoirs located in the engine compartment. Our invention is hence applicable to any fuel supply systems involving a storage tank relatively remote from the engine, and a secondary vented reservoir located sufficiently near the engine to absorb heat therefrom.

It will be apparent from the foregoing that the apparatus of our invention includes a new and novel carburetion device comprising a housing enclosing an air-intake and fuel evaporation throat, an integrally attached fuel reservoir chamber, a fuel inlet opening into the reservoir chamber, at least one liquid fuel transfer port traversing the housing and communicating the throat with the reservoir chamber, means for maintaining a substantially constant liquid fuel level in the reservoir chamber against a supernatant vapor space, at least one balancing tube traversing the housing and connecting the supernatant vapor space in the fuel reservoir chamber with the throat, and a drain port opening from the bottom of the reservoir chamber.

Various other changes and modifications of this invention are apparent from the description of this invention and further modifications will be obvious to those skilled in the art. Such modifications and changes are intended to be included within the scope of this invention as defined by the following claims.

We claim:

1. In combination with an internal combustion engine, an improved liquid fuel delivery and conservation system adapted to minimize evaporative fuel losses, comprising in combination a remote fuel storage tank, a fuel induction device associated with said engine, an induction sys-

tem fuel reservoir chamber located near said engine, said chamber having a supernatant vapor space and having at least one vent to the atmosphere from said supernatant vapor space, fuel delivery means for delivering fuel from said storage tank to said fuel reservoir chamber, means for transferring fuel from said reservoir chamber to said fuel induction device, and a fluid drain conduit opening from said fuel reservoir chamber and communicating with the interior of said storage tank, said drain conduit being adapted to return fuel to said storage tank, and to empty said reservoir chamber when said fuel delivery means is inoperative.

2. A combination as defined in claim 1 wherein said fuel induction device is a carburetor, and said induction system fuel reservoir chamber is a float chamber provided with a float valve therein for controlling the rate of fuel inflow to maintain a constant liquid level therein.

3. A combination as defined in claim 2 wherein said supernatant vapor space of said reservoir chamber is vented to the atmosphere through an internal vent of said carburetor, and contains no external vents.

4. A combination as defined in claim 1 including a vent communicating with the atmosphere from the vapor space in said fuel storage tank.

5. A combination as defined in claim 4 wherein the vent opening from said storage tank is a first vapor conduit leading into and communicating with the vapor space in said fuel reservoir chamber, said storage tank being vented to the atmosphere through said first vapor conduit and a second vapor conduit comprising said vapor space and an internal vent of said fuel induction device.

6. A combination as defined in claim 1 including flow-regulating means in said drain conduit adapted to limit the flow rate from said fuel reservoir chamber to a value substantially lower than the delivery capacity of said fuel delivery means.

7. A combination as defined in claim 1 including a valve in said drain conduit, and control means for closing said valve during engine operation, and for opening the same substantially immediately upon stopping said engine.

8. A combination as defined in claim 1 including a pressure relief vent line leading from an intermediate point in said drain conduit and opening to the atmosphere.

9. In combination with an internal combustion engine, an improved liquid fuel delivery and conservation system adapted to minimize evaporative fuel losses, comprising in combination a fuel storage tank, a pressure relief valve in the upper portion of said storage tank adapted to maintain a small maximum positive pressure therein, a check valve in the upper portion of said storage tank adapted to maintain at least atmospheric pressure therein, an independently operable valve in the upper portion of said storage tank, means for maintaining said independently operable valve closed when said engine is in operation and for opening the same to the atmosphere substantially simultaneously with each cessation of engine operation, a carburetor having a fuel reservoir chamber with a supernatant vapor space and with at least one vent to the atmosphere from said supernatant vapor space, means for delivering fuel from said storage tank to said fuel reservoir chamber, a fluid drain conduit opening from said fuel reservoir chamber and communicating with the interior of said storage tank, said drain conduit being adapted to return fuel to said storage tank, and to empty said reservoir chamber, a throttle valve in said drain conduit, and control means for maintaining said throttle valve closed during operation of said engine and for opening the same immediately after opening of said independently operable valve.

10. A combination as defined in claim 9 wherein said throttle valve is a pressure operated valve which reciprocally operates in one direction at one pressure and operates in the opposite direction at a different pressure, and wherein said control means for said throttle valve comprises: a reservoir tank; a first conduit communicating said pressure operated valve with the interior of said reservoir tank; an orifice in said reservoir tank communicating the interior of said reservoir tank with a substantially constant pressure zone; a second conduit communicating the interior of said reservoir tank with a variable pressure zone, the pressure in said variable pressure zone being supplied by operation of said internal combustion engine and differing from the pressure in said substantially constant pressure zone by an amount sufficient to operate said pressure operated device in one direction; and a check valve in said second conduit adapted to close when the pressure of said variable pressure zone approaches the pressure of said constant pressure zone, said orifice having a flow capacity substantially less than the flow capacity of said second conduit and having a flow capacity which requires a substantial period of time to equalize the pressure between said constant pressure zone and said reservoir tank when said check valve closes.

11. An apparatus as defined in claim 10 wherein said period of time required to equalize the pressure is between about 3 and about 60 seconds.

12. A combination as defined in claim 9 including a fuel inlet port to said storage tank, a removable cap closing said inlet port, and wherein said pressure relief valve and said check valve are positioned in said removable cap.

13. A combination as defined in claim 9 wherein said supernatant vapor space of said reservoir chamber is vented to the atmosphere through an internal vent of said carburetor, and contains no external vents.

14. A carburetor for use in internal combustion engines comprising a housing enclosing an air-intake and fuel evaporation throat, a fuel reservoir chamber, a fuel inlet opening into said reservoir chamber, at least one liquid fuel transfer port traversing said housing and communicating said throat with said reservoir chamber, means for maintaining a substantially constant liquid fuel level in said reservoir chamber against a supernatant vapor space, at least one balancing tube traversing said housing and communicating said vapor space with said throat, and a drain port opening from the bottom of said reservoir chamber.

15. A method of reducing fuel evaporation from the fuel supply system of an internal combustion engine having a carburetor with a fuel-containing reservoir chamber, said chamber having a supernatant vapor space in vapor communication with the atmosphere, which method comprises: opening a drain port in the bottom of said chamber and emptying said chamber by draining retained fuel to the fuel storage tank immediately after stopping said engine, said drain port being closed while the engine is in operation; and closing said drain port after draining said chamber and prior to resumption of engine operation.

16. Apparatus adapted for use in conjunction with an intermittently operated internal combustion engine, which comprises in combination therewith a fuel reservoir chamber located near said engine, said fuel reservoir chamber having a supernatant vapor space and having at least one vent to the atmosphere from said vapor space; and cooling means, operative upon stopping said engine, adapted to prevent the residual heat of the engine from substantially increasing the temperature of fuel normally retained in said reservoir chamber after stopping said engine.

17. Apparatus according to claim 16 in which said cooling means comprises a cool fuel-containing storage tank located at a position more remote from said engine than said reservoir chamber, and transfer means for transferring fuel from said reservoir chamber to said storage tank when said engine is stopped.

18. In a system for delivering a volatile fuel to an internal combustion engine, wherein a fuel reservoir cham-

ber is located adjacent to the engine, said fuel reservoir chamber having at least one vent communicating its vapor space with the atmosphere, and said reservoir chamber is provided with fuel inlet, fuel outlet, and level control means for maintaining a substantially constant level of liquid fuel in said reservoir during operation of said engine, the improvement which comprises transfer means for transferring said fuel from said reservoir to a second chamber when said engine is not in operation.

19. An apparatus for use with an internal combustion engine which comprises in combination, a liquid fuel storage tank, a fuel induction device associated with said engine, an induction system fuel reservoir chamber vented to the atmosphere through an internal vent of said fuel induction device, and a conduit communicating the vapor space of said storage tank with an air intake channel of said internal combustion engine, and transfer means for transferring fuel from said reservoir chamber upon cessation of engine operation.

20. An apparatus for use with an internal combustion engine which comprises in combination, a liquid fuel storage tank, a fuel induction device associated with said engine, an induction system fuel reservoir chamber, a first conduit communicating the vapor space of said storage tank with the supernatant vapor space of said fuel reservoir chamber, and an internal vent communicating said supernatant vapor space with the air intake channel of said fuel induction device.

21. An operational delay apparatus for controlling a pressure operated device which reciprocally operates by changing pressure, which comprises: a substantially constant pressure source; a variable pressure source which is capable of attaining the same pressure as said constant pressure source as well as a pressure which differs from said constant pressure source by an amount sufficient to operate said pressure operated device; a reservoir tank communicating said pressure operated device with said variable pressure source; an orifice in said reservoir tank communicating the interior of said tank with said constant pressure source, said orifice having a flow capacity substantially less than the flow capacity between said reservoir tank and said variable pressure source; and a check valve located between said variable pressure source and said reservoir tank, said check valve being adapted to close only when the pressure of said variable pressure source approaches the pressure of said constant pressure source.

22. An apparatus as defined in claim 21 wherein said substantially constant pressure source is at a higher pressure than said variable pressure source.

23. An apparatus as defined in claim 21 wherein said substantially constant pressure source is at atmospheric pressure, and wherein said variable pressure source is at subatmospheric pressure.

24. A method of reducing fuel evaporation from the fuel supply system of an internal combustion engine having a carburetor with a fuel-containing reservoir chamber whose supernatant vapor space is in vapor communication with the atmosphere, which method comprises: transferring all of the retained fuel from said fuel-containing chamber to a remotely located cool fuel-containing storage tank within a short period of time after stopping said engine.

25. A method as defined in claim 24 wherein said period of time is not greater than about 4 minutes.

References Cited in the file of this patent

UNITED STATES PATENTS

1,286,528	Carson	Dec. 3, 1918
1,909,390	Ball et al.	May 16, 1933
2,285,830	Paget	June 9, 1942
2,364,605	Curtis	Dec. 12, 1944
2,618,292	Ring	Nov. 18, 1952
2,647,735	Haynie	Aug. 4, 1953
2,670,760	Erikson	Mar. 2, 1954
2,885,865	Muenger et al.	May 12, 1959
2,894,736	Wentworth	July 14, 1959