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FUEL SYSTEM FOR INTERNAL COMBUSTION ENGINES

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2 Sheets-Sheet 1

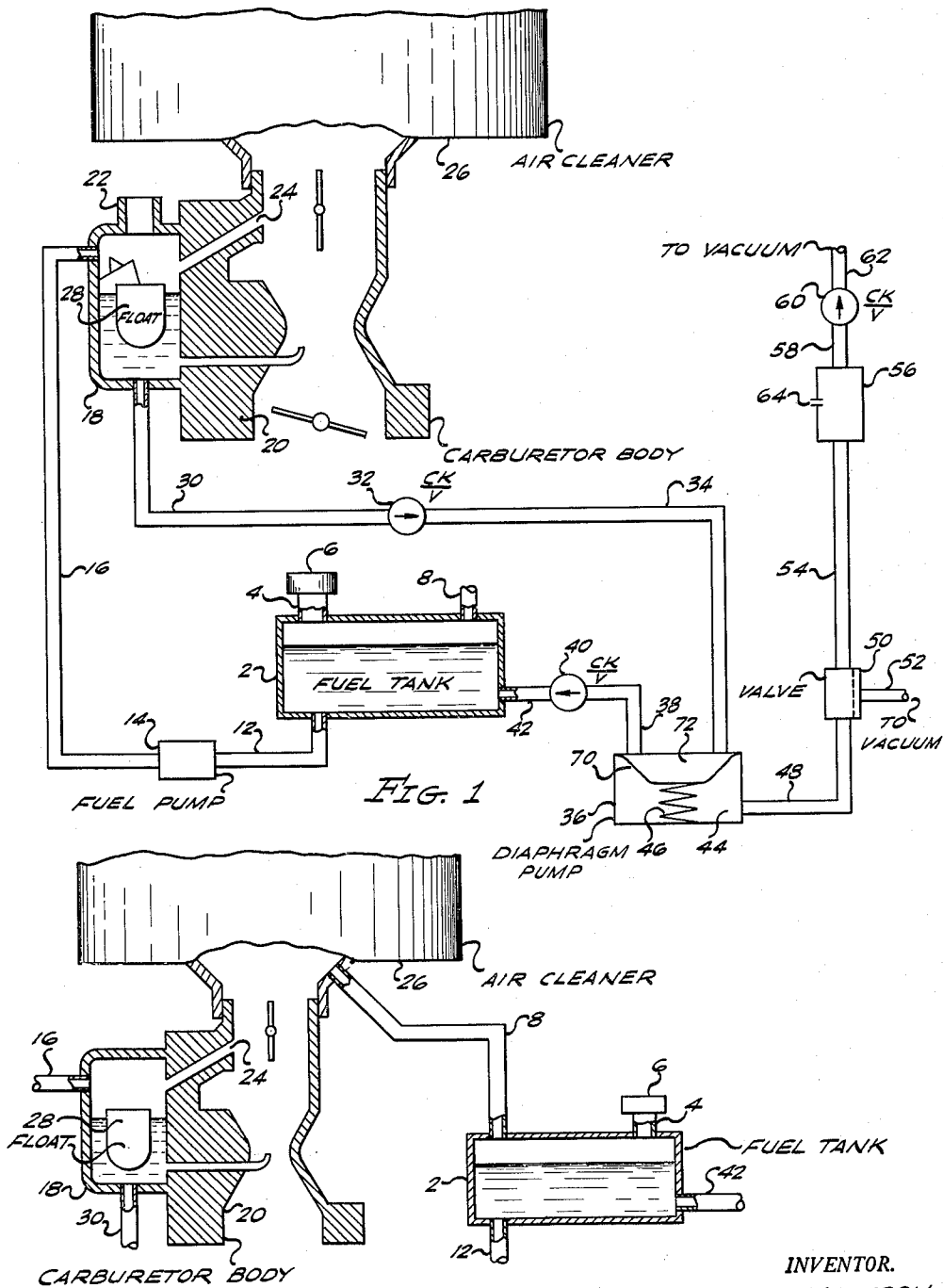


FIG. 1

FIG. 2

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2 Sheets-Sheet 2

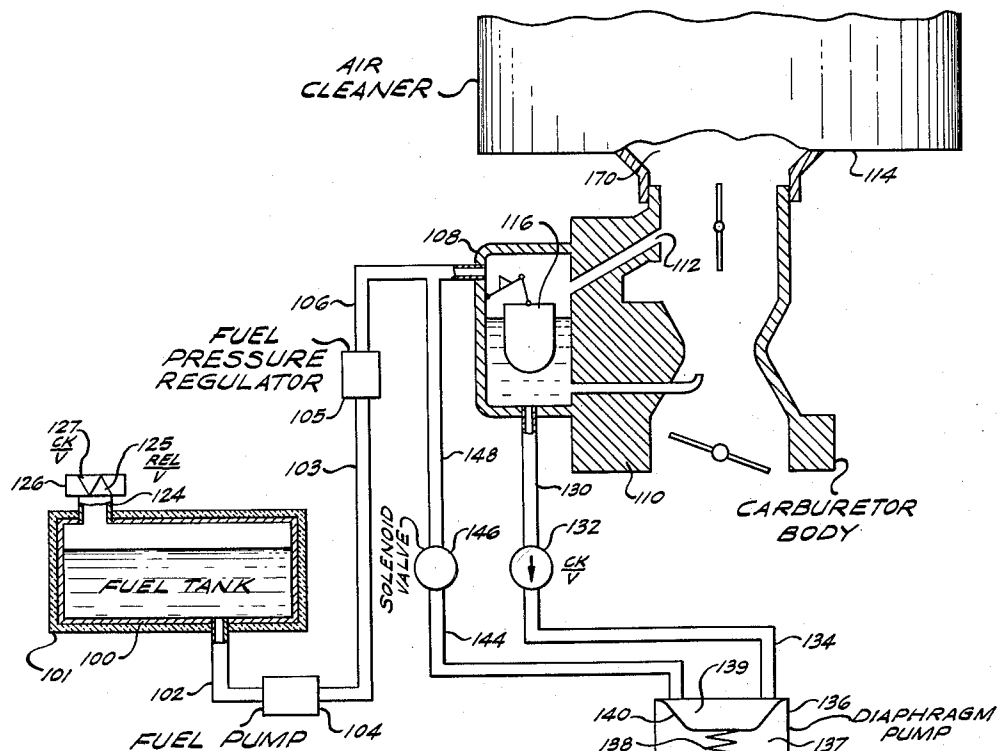


FIG. 3

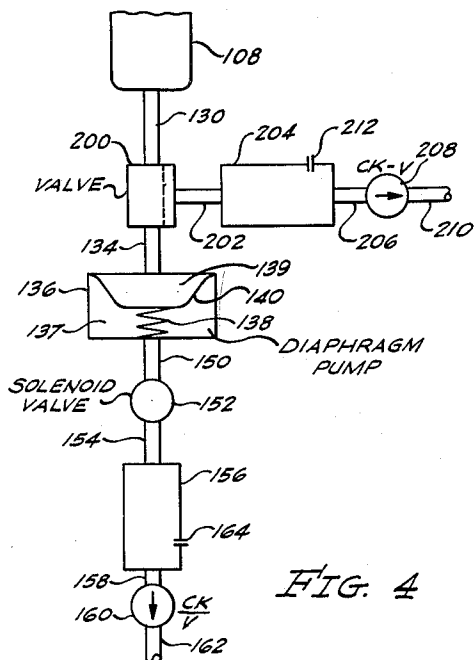


FIG. 4

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FUEL SYSTEM FOR INTERNAL COMBUSTION ENGINES

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19 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 throat 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

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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 economical operation.

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

Other and related objects will be apparent from the 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.

I have found that the foregoing objects and their attendant advantages can be realized in a conventional internal combustion engine, such as used in the propulsion of motor vehicles, by providing the float bowl of a conventional carburetor with a system which pumps the fuel from the carburetor float bowl to an alternate reservoir 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 embodiment of this invention in which the fuel emptied from the carburetor float bowl is pumped back to the primary fuel storage tank. Figure 2 is a further modification of Figure 1 wherein the tank vent line is in vapor communication with the air inlet channel of the carburetor. Figure 3 is a schematic diagram of another embodiment of this invention in which the pump chamber acts as the alternate fuel reservoir, and the same body of fuel pumped from the float bowl when the engine is stopped is returned to the float bowl when the engine is started. Figure 4 is a further modification of the apparatus of Figure 3 wherein the same line is used to remove fuel from and to return said fuel to the float bowl chamber. It is to be understood that although the float bowl emptying method and apparatus shown 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. But it also has practical use with engines using somewhat heavier fuels such as diesel engines, jet engines, 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 2 via inlet conduit 4. When fuel tank 2 has an adequate supply of volatile fuel, tank cap 6 seals inlet conduit 4. Tank vent 8 communicates with the atmosphere and, as is conventional with fuel storage tanks on motor vehicles, maintains fuel tank 2 at atmospheric pressure. Fuel is supplied to float bowl 18 of carburetor 20 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 electrical pump, a mechanical pump or the like. However, fuel pump 14 is preferably electrically operated so that operation thereof may start immediately when the igni-

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tion is turned on, thus filling float bowl 18 rapidly and independently of engine operation. The fuel enters carburetor float bowl 18 at a rate controlled by the characteristics of 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 2 via check valve 32, line 34, vacuum-operated diaphragm pump 36, line 38, check valve 40 and line 42. Check valve 32 can be located at any point between carburetor float bowl 18 and pump 36. Check valve 40 is located at any point between pump 36 and fuel tank 2. These check valves 32 and 40 are usually conventional check valves which open in response to a differential pressure of approximately one to two pounds per square inch. Return lines 30, 34, 38 and 42 can be constructed of $\frac{1}{8}$ or $\frac{1}{4}$ inch I.D. tubing such as is used for conventional fuel delivery lines.

The operation of diaphragm pump 36 in the fuel return system is controlled by a vacuum time delay system comprising conduit 48, valve 50 with its vacuum supply conduit 52, conduit 54, vacuum reservoir tank 56, conduit 58, check valve 60 and vacuum supply conduit 62. Vacuum supply conduits 52 and 62 are connected to any suitable source of vacuum, preferably the engine intake manifold. Diaphragm pump 36 may be conventional in design, and its volumetric stroke capacity is at least sufficient to empty completely the carburetor float bowl 18 in one suction stroke. As is conventional, diaphragm 70 of pump 36 is mechanically loaded against spring 46 which is compressed during the suction stroke. Diaphragm 70, illustrated at the end of the vacuum stroke with pump displacement chamber 72 filled with fuel, is constructed of any of the conventional diaphragm materials which are sufficiently flexible to act as diaphragms and are resistant to the deteriorating action of volatile fuels, e.g., Buna-S rubber. Pump 36 could be any type of pump whose suction stroke is sufficient to empty carburetor float bowl 18, e.g., a mechanically operated bellows pump or a piston and cylinder type pump.

The operation of the fuel supply system of this embodiment starts with the initial filling through inlet conduit 4 of fuel tank 2 until the desired tank level is obtained. Cap 6 is then secured thus sealing the end of inlet conduit 4. Prior to starting the internal combustion engine of which this fuel supply system is a part, valve 50 is open, diaphragm 42 of pump 36 is in its extreme fuel expulsion position with pump displacement chamber 72 at its minimum volume, check valves 32 and 40 are both closed, float bowl 18 is empty, and vacuum control chamber 44 of pump 36 is at approximately atmospheric pressure. When the engine is started vacuum actuated valve 50 immediately closes so as to prevent the vacuum supply from line 62 from actuating pump 36, which thus remains in its initial position. Meanwhile, fuel is being supplied to carburetor float bowl 18 via line 12, fuel pump 14, and line 16 in response to ignition or engine-supplied power. Float bowl 18 is quickly filled to the operative level as controlled by float valve 28. During the period of engine operation check valves 32 and 40 and vacuum-operated valve 50 remain closed, while check valve 60 is open bringing vacuum reservoir tank 56 to approximately engine manifold vacuum pressure. Any vapors which develop in float bowl 18 during engine operation travel via internal vent 24 to the other carburetor chambers and are thus swept into the combustion chamber of the engine and burned.

When the engine is shut off, fuel pump 14 no longer delivers fuel and the conventional vacuum manifold of

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the internal combustion engine returns to atmospheric pressure thus dissipating the vacuum source which was holding valve 50 closed. In response thereto valve 50 opens immediately, thus opening pump control chamber 44 to vacuum reservoir tank 56. As a result the pressure in pump control chamber 44 drops temporarily to a subatmospheric value thus allowing diaphragm pump 36 to take its vacuum stroke compressing spring 46. Check valve 32 then opens and the fuel remaining in carburetor float bowl 18 flows into pump chamber 72 via line 30, check valve 32, and line 34. When the engine manifold vacuum returned to atmospheric pressure upon engine stoppage, check valve 60 automatically closed simultaneously with the opening of valve 50 thus allowing vacuum reservoir tank 56 to return gradually to atmospheric pressure by the entrance of air through orifice 64. The purpose of this vacuum time delay system is to delay the fuel expulsion stroke of diaphragm pump 36 until all the fuel from bowl 18 has been transferred to chamber 72 on the suction stroke of the pump. As the pressure on the control side of diaphragm pump 36 approaches atmospheric it reaches a point at which spring 46 is able to supply the two pounds per square inch differential required to open check valve 40, and diaphragm pump 36 takes its pressure stroke thus emptying pump displacement chamber 72 into fuel tank 2 via line 38, check valve 40 and line 42. The delay in the taking of this pressure stroke is thus a function of the size of orifice 64 and vacuum reservoir tank 56. 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 gives the desired time delay can be used. Operative time delay periods of about 3 to 60 seconds are contemplated. Thus, with the above-described mode of operation there is little fuel loss through external vent 22 or internal vent 24 to the atmosphere, since the highly volatile fuel has been immediately removed from the carburetor float bowl after the engine is stopped. When the engine is restarted, valve 50 closes 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. Valve 50 can be an electrical solenoid valve with appropriate circuiting usually in conjunction with the ignition circuit. Thus, valve 50 would be in the open position when the ignition is off and in the closed position when the ignition is turned on. Instead of the vacuum delay system used to control the cycling of pump 36, a conventional mechanical or electrical time delay system can also be used.

Line 42 can enter fuel tank 2 either in the vapor space at the top of the fuel tank or, preferably, as shown in Figure 1, the returned fuel from carburetor float bowl 18 can enter the bottom of fuel tank 2. Since this returned 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 returned fuel into the bottom of the cool body of fuel in tank 2.

Further modifications of the apparatus of Figure 1 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. I have found that if the fuel return system of my invention is used with an internal combustion engine, then external vent 22 can be plugged with no change in the normal satisfactory operation of the engine. 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 my invention with a high degree of success. Evaporation losses from the fuel system were materially reduced, with a resultant reduction in atmos-

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pheric pollution and in gross fuel consumption. It has been found that as a further means of reducing evaporative loss of volatile fuels, fuel tank 2 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 8. Any conventional insulating material can be used such as glasswool, asbestos, and the like.

A further modification of the apparatus of Figure 1 entails connecting tank vent 8 of the fuel tank 2 to external vent 22 of float bowl 18. Thus there is communication between the vapor space of fuel tank 2 and the vapor space of float bowl 18 which, during engine operation, will permit any vapors evaporating from fuel tank 2 to pass through tank vent 8 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. Tank vent 8 can also be returned to the air cleaner or to any location in the fuel induction assembly where fuel vapors from fuel tank 2 are carried into the combustion chamber of the internal combustion engine during engine operation. Tank vent 8 may also include a valve which seals tank 2 from the atmosphere during engine off periods and is open during engine operation.

Figure 2 illustrates a fragmentary view of the apparatus of Figure 1 incorporating the elimination of external vent 22 and the returning of tank vent 8 to the air intake channel of carburetor 20. Thus, any vapors evaporating from fuel tank 2 flow through tank vent 8 to the air inlet of carburetor 20, and subsequently, during engine operation, these fuel vapors are carried into the engine and burned. The apparatus of Figure 2 operates in an identical manner to the apparatus of Figure 1 except for the disposal of the fuel vapors from fuel tank 2.

Fuel tank 2 can be operated as a pressured fuel tank, and in that instance tank vent 8 is sealed off and tank cap 6 is replaced with 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 in the fuel cap opens so that it is impossible for a vacuum to develop within fuel tank 2. When pressures above about 2 p.s.i.g. develop, a relief valve in the fuel cap opens to reduce the pressure to about 2 p.s.i.g. With a pressured fuel tank it is occasionally necessary to insert either a fuel pressure regulator or a check valve such as check valve 40, or both, between fuel pump 14 and float bowl 18 to prevent excessive fuel delivery pressures to float bowl 18, and to prevent possible fuel flow while the engine is stopped because of excessive fuel tank pressure.

Referring now more particularly to Figure 3, the apparatus here shown comprises another embodiment of my float bowl emptying system. The volatile hydrocarbon fuel enters fuel tank 100 via inlet conduit 124. The outer surface of fuel tank 100 is covered with insulation 101 comprising two layers of heavy asbestos paper, one layer of aluminum foil and an outer layer of asbestos cloth. The entire insulation thickness is approximately 1/2 inch. 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 0 and about 2 p.s.i.g. The design of these 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 a vacuum to develop within fuel tank 100. When a pressure above about 2 p.s.i.g. develops, 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, line 103, fuel

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pressure regulator 105 and line 106. Fuel pump 104 in this embodiment is an electrically operated pump which functions whenever the ignition is on and ceases operation, thus blocking the passage of fuel, when the ignition is off. Fuel pump 104 could, however, 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 to maintain 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 to float bowl 108 and thus acts as a metering device to maintain a substantially constant level of fuel within carburetor float bowl 108.

In the present modification, instead of returning the fuel from float bowl 108 to fuel tank 100, provision is made for retaining the float bowl fuel in an independent reservoir when the engine is inoperative. In the modification illustrated in Figure 3, this independent reservoir is pump displacement chamber 139, into which the float bowl fuel is withdrawn via a tubular line 130 opening from the bottom of float bowl 108, check valve 132, line 134 and pump 136. A separate return system is provided for returning this fuel from pump 136 to float bowl 108 upon resumption of engine operation. This return system comprises line 144, solenoid valve 146 and line 148 which enters float bowl 108 at a point above the normal liquid level. Line 148 may enter float bowl 108 at any point and, in fact may use the same opening as that used by line 130 by e.g. inserting a T fitting in the opening in the float bowl chamber bottom. The operation of diaphragm pump 136 is controlled by a vacuum time delay system comprising conduit 150, solenoid valve 152, conduit 154, vacuum reservoir tank 156, conduit 158, check valve 160 and vacuum supply conduit 162.

The operation of the fuel supply system of this embodiment entails filling fuel tank 100 through inlet conduit 124 with liquid fuel until a desired level is obtained. Pressure cap 126 is then secured to conduit 124 sealing the end thereof. Prior to starting the internal combustion engine of which this particular fuel supply system is a part, solenoid valve 146 is closed and solenoid valve 152 is open. Valves 146 and 152 are connected by appropriate conventional circuitry to the ignition switch which controls the opening and closing of these valves. When the ignition is on, valve 146 is open and valve 152 is closed. When the ignition is off, valve 146 is closed and valve 152 is open. Prior to resumption of engine operation, diaphragm 140 of pump 136 is in its extreme fuel-intake position, with pump displacement chamber 136 at its maximum volume and filled with fuel. Check valve 132 is closed, float bowl 108 is empty, control chamber 137 of pump 136 is at approximately atmospheric pressure and spring 138 is compressed in loaded position.

When the ignition is turned on with subsequent starting of the engine, solenoid valve 152 closes and solenoid valve 146 opens, thus allowing diaphragm pump 136 to take its pressure stroke which immediately fills carburetor float bowl 108 with the fuel from pump displacement chamber 139 via line 144, valve 146 and line 148. Subsequently, within a few seconds, fuel is supplied to carburetor float bowl 108 via line 102, fuel pump 104, line 103, fuel pressure regulator 105 and line 106. If the fuel returned by the pressure stroke of pump 136 did not fill float bowl 108 to the normal operating level, then the operation of fuel pump 104 now does this, and it is filled to the operative level as controlled by float valve 116. If the pressure stroke of pump 136 has filled float bowl 108 to its normal fuel level, then float valve 116 will re-

strict the entrance of line 106 into float bowl 108 sufficiently to prevent further fuel from flowing until engine consumption requires it. 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 chamber of the engine and burned. Also during the period of engine operation, check valve 132 remains closed and check valve 160 is opened bringing vacuum reservoir tank 156 to approximately the engine intake manifold vacuum pressure.

When the engine is shut off with the contemporaneous turning off of the ignition switch, solenoid valve 146 closes and solenoid valve 152 opens. The opening of valve 152 drops the pressure of pump control chamber 137 to a subatmospheric value thus allowing diaphragm pump 136 to take its vacuum stroke compressing spring 138. Check valve 132 opens and the fuel remaining in carburetor float bowl 108 flows into the pump displacement chamber 139 via line 130, check valve 132 and line 134. When the engine intake manifold vacuum returned to atmospheric pressure upon engine stoppage, check valve 160 automatically closed, simultaneously with the opening of valve 152, thus allowing vacuum reservoir tank 156 to return gradually to atmospheric pressure by the entrance of air through orifice 164. Thus within a short time, e.g., three to sixty seconds, pump control chamber 137 returns to atmospheric pressure, preparing pump 136 for its pressure stroke which occurs upon resumption of engine operation. The operation of the vacuum time delay system for pump 136 operates in the same manner as the previously described vacuum delay system for pump 36 of Figure 1.

The fuel system of Figure 3 as above described is not limited to the use of solenoid actuated valves. Valves 146 and 152 can be mechanical valves operated manually, or vacuum actuated valves which operate from the engine intake manifold vacuum as previously discussed with the apparatus of Figure 1. Fuel tank 100 may also be vented directly to the atmosphere, or to a vapor space communicating with an air intake channel to the engine, e.g., carburetor mouth 170.

Referring now more particularly to Figure 4, the apparatus here shown is a fragmentary view of float bowl 108 of Figure 3 with a modified float bowl emptying and refilling system. The fuel supply system of Figure 4 is identical to Figure 3 with the following exceptions: (1) line 148, solenoid valve 146, and line 144 of Figure 3 have been eliminated; (2) check valve 132 has been removed and replaced by vacuum actuated valve 200; (3) a vacuum reservoir tank 204, line 206, check valve 208, and vacuum supply line 210.

The operation of fuel pump 136 and its vacuum delay system is the same in the modification illustrated in Figure 4 as in the apparatus of Figure 3. Thus the embodiment in Figure 4 is concerned primarily with a modification comprising a single connecting fuel line between float bowl 108 and pump 136. When the engine is running, valve 200 is held open by the engine intake manifold vacuum transmitted via line 202, vacuum reservoir tank 204, line 206, check valve 208 and vacuum supply line 210. When the engine is shut off, valve 200 remains open for a period sufficient to allow pump 136 to complete its suction stroke. This delay in the closing of valve 200 is controlled by the associated vacuum time delay system. When the engine intake manifold vacuum returns to atmospheric pressure upon engine stoppage, check valve 208 automatically seats and closes, thus allowing vacuum reservoir tank 204 to return gradually to atmospheric pressure by the entrance of air through orifice 212. Thus, within a few seconds the control side of vacuum operated valve 200 approaches atmospheric pressure which closes valve 200 prior to the repressuring of pump control chamber 137 of pump 136. It is necessary that valve 200 be completely closed prior to the start of the pressure stroke of pump 136. Thus, the

vacuum time delay for valve 200 must be substantially less than the delay associated with pump 136. Typical delays are 3 to 8 seconds for the closing of valve 200, and 15 to 60 seconds for the repressuring of pump chamber 137 of pump 136.

When the engine is started valve 200 opens under the effect of engine intake manifold vacuum and valve 152 closes, allowing pump 136 to take its pressure stroke. Valve 200 opens almost immediately since vacuum reservoir tank 204 is comparatively small and reflects the cranking vacuum (about 5 to 7 inches of Hg) immediately to the control side of valve 200. Float bowl 108 fills immediately, as previously discussed with regard to Figure 2, making available for engine operation an adequate fuel level in float bowl 108.

Although the fuel systems shown in Figures 1, 2, 3 and 4 are illustrated with a single-bowl carburetor, the method and apparatus of my invention have been successfully applied to an engine having a two-bowl carburetor, and any number of carburetors or bowls can be integrated into the system.

While Figures 1, 2, 3 and 4 all have a simple positive displacement pump illustrated (pumps 36 and 136) as the means for emptying the float chamber, and in Figures 3 and 4 for refilling, it is to be understood that my invention also can employ any pumping means for this purpose. With the use of a pump such as a centrifugal pump, a gear-type rotary pump, a reciprocating pump and the like whose pump chamber volume is smaller than the float bowl volume, it is necessary to have an alternate reservoir and the pump must operate long enough to empty the float bowl. Where the pump also refills the float bowl, an adequate refilling time is also provided. A wide variety of time delay systems are commercially available including electronic delays utilizing conventional delay circuitry, mechanical delays such as spring-operated cams and the vacuum delays shown in Figures 1, 2, 3 and 4. Since many of these pumps are electrically driven, any of the conventional control or switching devices which will provide power to the pump motor for a limited period of time and then break the power supply circuit are satisfactory for establishing the pump operating sequence.

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. The novel apparatus of my invention can easily be incorporated into the assembly of new vehicles, but even more important is the fact that the apparatus may be readily installed on existing vehicles.

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

While the method and apparatus of my invention deals primarily with solving the evaporative loss problem by pumping the fuel from the high temperature vented chambers associated with internal combustion engines, there are other approaches equally useful. All vents from these fuel-containing chambers can also be shut off from the atmosphere by appropriate valving during engine-off periods. This requires blocking in (1) the internal vents, (2) the external vents, if any, and (3) in some cases the fuel conduit leading from the float chamber to the jet in the throat of the carburetor. The fuel inlet conduit conventionally has a check valve in it which prevents flow back through the

fuel pump. This closing in of the float chamber, or any similar vented fuel reservoir, can be accomplished either by modifying existing fuel induction systems, or by incorporating the requisite valves, manifolds, etc., into the design of new carburetors. The valves used can be any conventional mechanical, vacuum-operated, or electrically operated valves, but preferably would be solenoid valves whose operation is controlled by the ignition switch. This sealing of the carburetor fuel reservoir chamber can be used in combination with all of the methods and apparatus described in relation to Figures 1, 2, 3 and 4, whereby pressures developed within the sealed off chambers can be relieved by transferring the fuel from the hot carburetor chambers to more remote pump chambers.

Since a primary purpose of the reservoir emptying by pumping is to keep this reservoir fuel cool during engine-off periods, it is contemplated that any method of removing the fuel to a cool space will accomplish the purpose of the invention, namely reduction of evaporative loss during the "hot soak" period. Thus, removal to a cool space can include transfer to any secondary reservoir, or the main fuel storage tank, with means provided for returning this fuel to the fuel induction system when the engine is started. Obviously, cooling of the fuel in the carburetor reservoir chambers "in situ" can also reduce evaporative losses and the isolation and insulation of these carburetor fuel chambers, i.e., float chambers and the like, can greatly reduce the effect of the "hot soak" period.

Various other changes and modifications 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:

I claim:

1. In combination with an internal combustion engine, an improved liquid fuel delivery and conservation system comprising in combination a remote fuel storage tank, a fuel induction device associated with said engine, an induction system fuel reservoir chamber located near said engine and having at least one vent to the atmosphere, 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 pumping means operative substantially immediately upon stopping said engine for transferring fuel from said induction system reservoir chamber to an alternate fuel reservoir.

2. A combination as defined in claim 1 including pumping means operative substantially immediately upon starting said engine for transferring fuel from said alternate fuel reservoir to said induction system fuel reservoir.

3. A combination as defined in claim 1, including a layer of thermal insulating material surrounding at least the major exterior surface area of said fuel storage tank.

4. A combination as defined in claim 1 including a vent line opening from the vapor space in said fuel storage tank and communicating with an air intake channel of said internal combustion engine.

5. A combination as defined in claim 1 including a vent line opening from the vapor space in said storage tank and communicating with the vapor space in said induction system fuel reservoir chamber.

6. A combination as defined in claim 1 including a vent line opening from the vapor space in said storage tank and communicating with the air inlet of said fuel induction device.

7. A combination as defined in claim 1 wherein said alternate fuel reservoir is said remote fuel storage tank.

8. A combination as defined in claim 1 including a fuel inlet port to said remote fuel storage tank, a removable cap sealing said inlet port wherein said cap

has positioned therein a pressure relief valve adapted to maintain a small maximum positive pressure within said tank and a check valve adapted to maintain at least atmospheric pressure within said tank.

9. A combination according to claim 1 wherein said pumping means comprises a reciprocating positive-displacement pump with a displacement chamber of volume capacity at least equal to the fuel holding capacity of said induction system fuel reservoir, and wherein said alternate fuel reservoir is said pump displacement chamber.

10. 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 delivery to maintain a constant liquid level therein.

11. A combination as defined in claim 1 wherein said fuel reservoir chamber is vented only to the throat of said carburetor and contains no external vents.

12. In combination with an internal combustion engine, an improved liquid fuel delivery and conservation system comprising in combination a fuel storage tank, a carburetor having a fuel reservoir chamber with at least one vent to the atmosphere, means for delivering fuel from said storage tank to said fuel reservoir chamber, means for transferring fuel from said reservoir chamber to said carburetor, a return fuel system for emptying said fuel reservoir chamber immediately upon stopping said engine comprising a pump, a drain conduit opening from said fuel reservoir chamber and communicating with said pump, a check valve in said drain conduit adapted to permit flow only from said fuel reservoir chamber, a discharge conduit adapted to deliver fuel from said pump to an alternate fuel chamber, a check valve in said discharge conduit adapted to permit flow only from said pump, and means for actuating said pump for a short time following each cessation of engine operation.

13. Apparatus as defined in claim 12 wherein said alternate fuel chamber is said fuel storage tank.

14. In combination with an internal combustion engine, an improved liquid fuel delivery and conservation system comprising in combination a fuel storage tank, a carburetor having a fuel reservoir chamber with at least one vent to the atmosphere, means for delivering fuel from said storage tank to said fuel reservoir chamber, means for transferring fuel from said reservoir chamber to said carburetor, a fuel transfer and storage system for emptying said fuel reservoir chamber immediately upon stopping said engine and for refilling the same upon starting said engine, said transfer and storage system comprising a positive displacement pump having a displacement chamber at least equal in volume to the fuel capacity of said reservoir chamber, a drain conduit opening from said fuel reservoir chamber and communicating with the displacement chamber of said pump, a check valve in said drain conduit adapted to permit flow only from said fuel reservoir chamber, a discharge conduit adapted to deliver fuel from the displacement chamber of said pump to said fuel reservoir chamber, a throttle valve in said discharge conduit, control means for opening said throttle valve immediately upon starting said engine and for closing the same immediately after stopping said engine, means for activating a fuel intake stroke of said pump upon stopping said engine, and means for activating a fuel expulsion stroke of said pump upon starting said engine.

15. In combination with an internal combustion engine, an improved liquid fuel delivery and conservation system comprising in combination a fuel storage tank, a carburetor having a fuel reservoir chamber with at least one vent to the atmosphere, means for delivering fuel from said storage tank to said fuel reservoir chamber, means for transferring fuel from said reservoir chamber to said carburetor, a fuel transfer and storage system for emptying said fuel reservoir chamber immediately upon

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stopping said engine and for refilling the same upon starting said engine, said transfer and storage system comprising a positive displacement pump having a displacement chamber at least equal in volume to the fuel capacity of said reservoir chamber, a conduit opening from said fuel reservoir chamber and communicating with the displacement chamber of said pump, a throttle valve in said conduit, control means for closing said throttle valve a short time after cessation of engine operation and for opening the same immediately upon starting said engine, means for activating a fuel intake stroke of said pump upon stopping said engine, and means for activating a fuel expulsion stroke of said pump upon starting said engine.

16. A method of reducing fuel evaporation from the fuel supply system of an internal combustion engine having a fuel induction system with a fuel-containing chamber in fluid communication with the atmosphere, which method comprises emptying said chamber by pumping re-

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tained fuel therefrom into an alternate fuel reservoir immediately upon stopping said engine.

17. A method as described in claim 16 wherein said alternate fuel reservoir is the fuel storage tank of said fuel supply system.

18. A method as described in claim 16 wherein said retained fuel, pumped to an alternate fuel reservoir immediately upon stopping said engine, is pumped back into said fuel-containing chamber immediately upon starting said engine.

19. A method as described in claim 18 wherein said alternate fuel reservoir is a pump displacement chamber.

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