

[54] **DUAL FUEL SYSTEM**  
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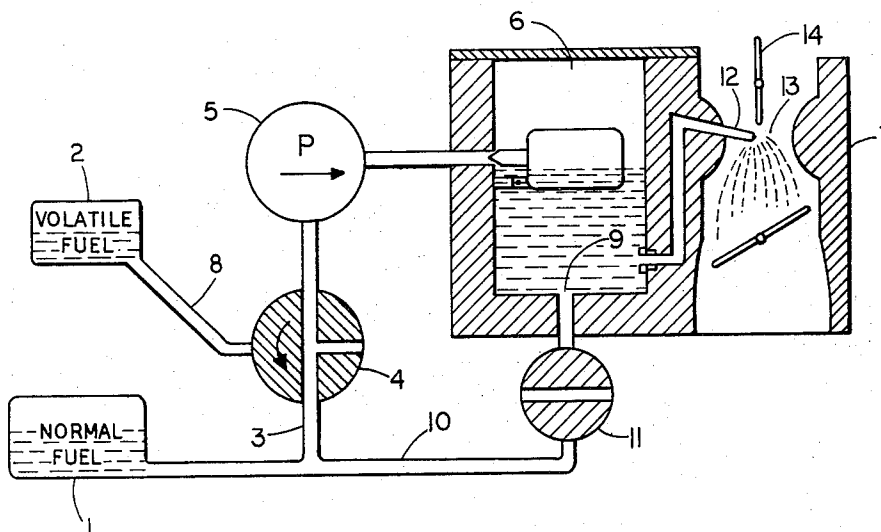
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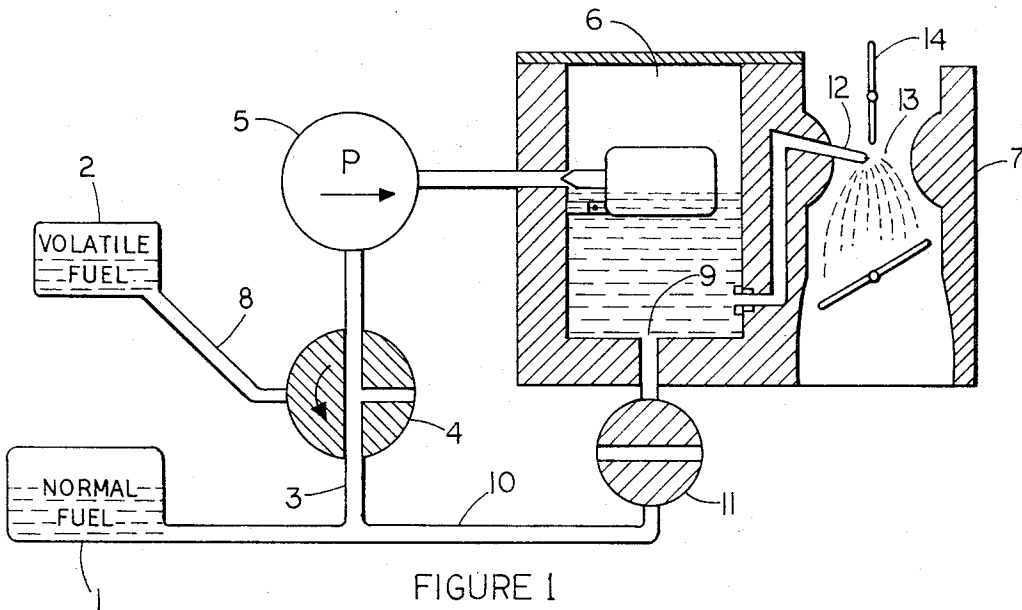
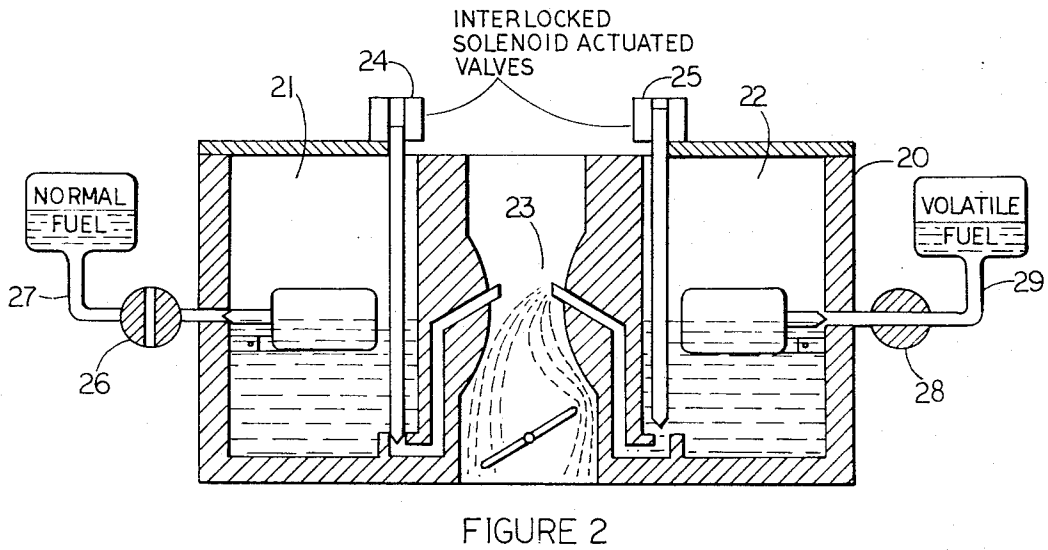
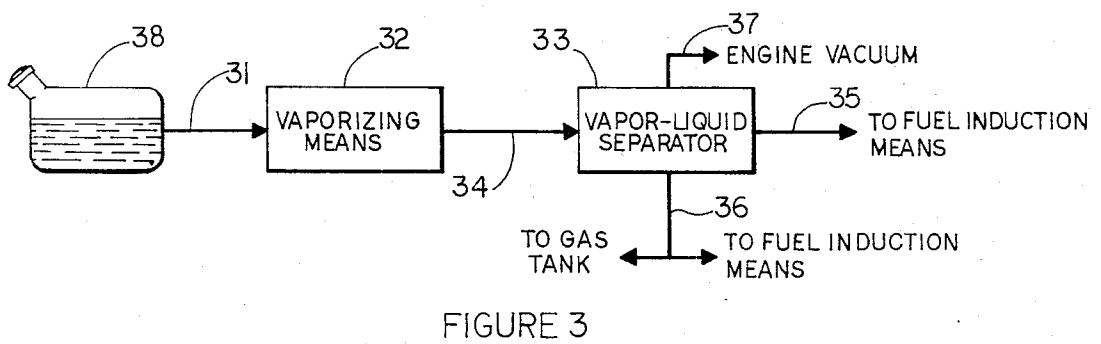
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[57] **ABSTRACT**  
A fuel system for a spark ignited internal combustion engine which feeds gasoline and a volatile gasoline fraction to the engine has a volatile fuel generation means with an appropriate valve switching system designed to allow operation of the engine on the volatile fuel during start and warm-up and then switch to normal fuel during warmed-up operation. The self-generation system utilizes engine vacuum as an aid in vaporizing a portion of the normal gasoline.

**3 Claims, 5 Drawing Figures**







## DUAL FUEL SYSTEM

## BACKGROUND OF THE INVENTION

The exhaust gas of internal combustion engines contains various amounts of unburned hydrocarbons, carbon monoxide, and nitrogen oxides ( $\text{NO}_x$ ). Emission of these materials to the atmosphere is undesirable. The problem is more acute in urban areas having a high concentration of motor vehicles.

During recent years, researchers have investigated extensively means of reducing exhaust emission. This research has been quite fruitful. As a result, present-day automobiles emit but a fraction of undesirable materials compared to those of less than a decade ago. These improved results have come about through such means as improved carburetion, ignition timing modifications, exhaust recycle, exhaust manifold air injection, use of lean air/fuel ratios, positive crankcase ventilation, and the like.

Despite the tremendous advances that have been made, further improvements are desirable. Federal standards by 1975 are expected to require reduction of emissions to only about 10 percent of the level of 1970. A major obstacle in achieving further reduction in exhaust emissions is the fact that the engine requires a richer air/fuel mixture during start and warm-up. During this period exhaust emissions of even the lowest emitting engine is appreciably increased. In the case of carburetor induction engines, the required richer air/fuel mixture is usually attained by placing a choke valve in the air passage above the carburetor venturi, which serves to restrict air flow. In most, but not all, gasoline-powered vehicles the choke is automatically controlled by engine temperature. As soon as the engine reaches an adequate operating temperature (i.e., a temperature at which it can operate smoothly without choking), the choke opens. In normal operation this takes about 2-3 minutes.

In the past, attempts have been made to eliminate the need for this rich operating warm-up period by operating the engine on liquid petroleum gas (LPG) during the warm-up period and switching to gasoline after operating temperature is attained. A drawback of this system is that it requires the vehicle operator to obtain two different kinds of fuel—gasoline and LPG. Of even greater consequence is the fact that the use of a liquid an gaseous fuel requires a separate metering system for each fuel. For example, the LPG fuel system is separate from the gasoline fuel system and provides LPG vaporization, pressure regulation, and finally, vapor induction into the intake air stream through a separate metering jet. Because of this, the system using LPG fuel is considered impractical.

An object of the present invention is to provide a fuel induction system that results in lower exhaust emissions. A further object is to provide a fuel induction system that allows an engine to start and warm-up without the necessity of operating the engine at a rich air/fuel ratio. A still further object of the invention is to provide a novel liquid fuel system with self-generation of the more volatile liquid fuel from the normal gasoline fuel, thus eliminating the necessity of the vehicle operator obtaining two separate fuels. Another object is to provide a method of operating a gasoline engine in a manner that will result in reduced exhaust emissions.

## SUMMARY OF THE INVENTION

The present invention in its broadest aspect relates to a novel fuel system for a spark ignited internal combustion engine (hereinafter simply referred to as an engine) with a self-generation system for producing a liquid hydrocarbon fuel of the lower gasoline boiling range referred to hereafter as a "volatile gasoline fraction" and the method of accomplishing the generation of the volatile gasoline fraction in the engine fuel system. Therefore, this invention provides in a novel fuel system a vacuum line connected to a source of engine vacuum, vaporizing means in communication with said vacuum line whereby a portion of the liquid hydrocarbon fuel of the gasoline boiling range, referred to hereafter as gasoline, is vaporized, vapor-liquid separator means connected to said vaporizing means whereby the vapor produced in said vaporizing means is separated from the residual liquid fuel which is depleted in volatile components, and a volatile fuel conduit for delivery of said vapor to the fuel induction means of said engine for operating during a selected period of start and warm-up. In a preferred aspect of the invention a heater is used to aid vaporization. In another preferred aspect the vaporizing means is responsive to a pressure difference caused by opening a valve in the vacuum line and causing reduced pressure to develop in the vaporizing means. When the pressure difference attains a predetermined level, gasoline from the tank is drawn into the vaporizing means and a portion thereof is volatilized. In another preferred aspect of the invention condensing means are connected to the vaporizing means whereby the vapor is substantially completely condensed to form a liquid volatile gasoline fraction or "condensate." In a further preferred aspect of the invention, a vacuum chamber having a lower section and an upper section is connected to the condensing means whereby the condensate is collected in the lower section and pumped through a one-way check valve to a volatile fuel storage tank; and the upper section is connected to the source of engine vacuum and maintained under substantially reduced pressure during operation of the volatile fuel generation system.

Another broad aspect of this invention is the method of operating an engine having a fuel system which feeds gasoline and a volatile gasoline fraction to said engine, the improvement comprising using engine vacuum to vaporize a portion of gasoline and separating the vapor from the residual liquid thereby producing a volatile gasoline fraction for operating said engine during a selected period. In another preferred aspect of this invention, the vapor is condensed forming condensate which is stored in a volatile fuel storage container for delivery to the fuel induction means during start and warm-up. A still further aspect of the invention is the method wherein the residual liquid fuel from the vaporization which is separated from the vapor and is depleted in volatile components is stored in a volatile depleted fuel storage container for delivery to the fuel induction means during warmed-up operation of said engine. In another preferred aspect the method includes heating the gasoline to aid vaporization. A still further preferred aspect of the invention is the method of using engine vacuum wherein the vacuum is supplied from either the intake manifold or a venturi in a carburetor.

## DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic of the basic dual liquid fuel system showing a reservoir for both volatile fuel and normal gasoline and conduits for delivering either through a switching valve to the fuel bowl of the carburetor. Also shown is a carburetor drain conduit having a valve which allows the carburetor to drain when the engine is turned off.

FIG. 2 is a cross-section of a carburetor having separate fuel bowls for the normal gasoline and the volatile fuel and interlocked valves for switching from one fuel to the other. The drawing shows the valves functioning to permit delivery of the fuel from the volatile fuel bowl such as would occur during start and warm-up.

FIG. 3 is a schematic representation of the self-generation system for producing the volatile fuel in broad conceptual aspects showing a fuel line leading into a vaporizer which is connected to a vapor-liquid separator having a vacuum line, volatile fuel line, and residual fuel line.

FIG. 4 is a schematic of the dual fuel system's volatile fuel self-generation system including a vaporizing means, a vapor-liquid separator having a condenser for the volatile fuel and a vacuum chamber in which the vapor space is connected to the source of engine vacuum.

FIG. 5 is a schematic of the dual liquid fuel system showing the connection of the volatile fuel self-generation system of FIG. 4 to a carburetor on an internal combustion engine. Fuel switching valves are shown for delivery of either volatile fuel or normal gasoline to the engine. Vent lines and pumps are shown.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, a preferred embodiment of the invention is a fuel delivery system for a gasoline operated spark ignited internal combustion engine adapted to feed gasoline and a volatile gasoline fraction to the engine having a gasoline tank 1 for gasoline and a container for liquid hydrocarbon fuel of the lower gasoline boiling range 2.

Gasoline is a mixture of hydrocarbons having a boiling range of from about 80°F to about 430°F as measured by ASTM method D-86. Of course, these mixtures can contain individual constituents boiling above or below these figures. These hydrocarbon mixtures contain aromatic hydrocarbons, saturated hydrocarbons and olefinic hydrocarbons. The bulk of the hydrocarbon mixture is obtained by refining crude petroleum by either straight distillation or through the use of one of the many known refining processes, such as thermal cracking, catalytic cracking, catalytic hydroforming, catalytic reforming, and the like. Generally, the final gasoline is a blend of stocks obtained from several refinery processes. The final blend may also contain hydrocarbons made by other procedures such as alkylate made by the reaction of C<sub>4</sub> olefins and butanes using an acid catalyst, such as sulfuric acid or hydrofluoric acid.

Preferred gasolines are those having a Research Octane Number of at least 85. A more preferred Research Octane Number is 90 or greater. It is also preferred to blend the gasoline such that it has a content of aromatic hydrocarbons ranging from 10 to about 60 volume percent, an olefinic hydrocarbon content ranging from 0 to about 30 volume percent, and a saturate hydrocar-

bon content ranging from about 40 to 80 volume percent, based on the whole gasoline.

In order to obtain fuels having properties required by modern automotive engines, a blending procedure is generally followed by selecting appropriate blending stocks and blending them in suitable proportions. The required octane level is most readily accomplished by employing aromatics (e.g., BTX, catalytic reformat, or the like), alkylate (e.g., C<sub>6-9</sub> saturates made by reacting C<sub>4</sub> olefins with isobutane using a HF or H<sub>2</sub>SO<sub>4</sub> catalyst), or blends of different types.

The balance of the whole fuel may be made up of other components such as other saturates, olefins, or the like. The olefins are generally formed by using such procedures as thermal cracking, catalytic cracking and polymerization. Dehydrogenation of paraffins to olefins can supplement the gaseous olefins occurring in the refinery to produce feed material for either polymerization or alkylation processes. The saturated gasoline components comprise paraffins and naphthenes. These saturates are obtained from (1) virgin gasoline by distillation (straight run gasoline), (2) alkylation processes (alkylates), and (3) isomerization procedures (conversion of normal paraffins to branched-chain paraffins of greater octane quality). Saturated gasoline components also occur in so-called natural gasoline. In addition to the foregoing, thermally cracked stocks, catalytically cracked stocks and catalytic reformates contain saturated components.

Utilization of non-hydrocarbon blending stocks or components in formulating the fuels used in this invention is feasible and, in some instances, may actually be desirable. Thus, use may be made of methanol, tertiary butanol and other inexpensive, abundant and non-deleterious oxygen-containing fuel components.

The normal gasoline may contain any of the other additives normally employed to give fuels of improved quality, such as tetraalkyllead antiknocks including tetramethyllead, tetraethyllead, mixed tetraethyltetramethyllead, and the like. They may also contain antiknock quantities of other agents such as cyclopentadienyl nickel nitrosyl, methylcyclopentadienyl manganese tricarbonyl, and N-methyl aniline, and the like. Antiknock promoters such as tert-butyl acetate may be included. Halohydrocarbon scavengers such as ethylene dichloride, ethylene dibromide and dibromo butane may be added. Phosphorus-containing additives such as tricresyl phosphate, methyl diphenyl phosphate, diphenyl methyl phosphate, trimethyl phosphate, and tris( $\beta$ -chloropropyl)phosphate may be present. Antioxidants such as 2,6-di-tert-butylphenol, 2,6-di-tert butyl-p-cresol, phenylenediamines such as N-isopropylphenylenediamine, and the like, may be present. Likewise, the gasoline can contain dyes, metal deactivators, or any of the additives recognized to serve some useful purpose in improving the gasoline quality.

The liquid hydrocarbon fuel of the lower gasoline boiling range, referred to as a volatile gasoline fraction, is a hydrocarbon having a final boiling point below that of normal gasoline. In the present invention it is not necessary to place an exact value on this final boiling point and, in fact, it can vary when the novel fuel system is used with different engines. The requirement is that the volatile fuel have a final boiling point low enough such that the particular engine to which the novel fuel system is connected will start and operate smoothly during warm-up without resorting to a richer

air/fuel ratio than is required for operation at normal operating temperature. This is not to say that the use of a richer air/fuel ratio is excluded because under very cold conditions a slightly richer mixture may be required, especially to start the engine. This richer mixture is readily furnished by such means as choking the engine. However, the amount of time that the enriched air/fuel ratio is used will be substantially less than required without the novel fuel system of this invention; and accordingly, even when some choking is required, the overall exhaust emissions will be still greatly reduced by the use of the novel fuel system of this invention.

The optimum final boiling point for the volatile gasoline fraction to be used in the novel fuel system on a particular engine is best determined experimentally taking into account the conditions such as temperature and humidity, etc., under which the engine will be operated. A useful boiling range for the volatile gasoline fraction is from about 60–300°F. Especially good results are obtained in most applications using a volatile fraction having a normal boiling range of from about 70–150°F (ASTM D-86). The most preferred volatile fuel is made up of the light ends (low boilers) obtained from normal gasoline. In fact, embodiments of this invention, to be described in detail hereafter, include in the novel liquid fuel system means for removing the light ends from normal gasoline and using these as the volatile gasoline fraction during start and warm-up.

Referring again to FIG. 1, the dual fuel system includes a liquid fuel conduit 3 connecting gasoline tank 1 through fuel selector valve 4 to fuel pump 5 which connects to fuel bowl 6 of carburetor 7. The carburetor shown is a single venturi type but the fuel system is equally applicable to multiple venturi carburetors such as those having two, three, or four venturi.

Volatile fuel tank 2 is connected by volatile liquid fuel conduit 8 to fuel selector valve 4 which connects through fuel pump 5 to fuel bowl 6 of carburetor 7. As shown in FIG. 1, fuel selector valve 4 is set to deliver normal gasoline from gasoline tank 1 to carburetor 7. By revolving the selector valve counter-clockwise, as shown by the arrow, fuel selector valve 4 will function to deliver volatile fuel from volatile fuel tank 2 to carburetor 7.

Fuel bowl 6 has a fuel drain 9 which can drain residual fuel from the bowl 6 through drain conduit 10 to gasoline tank 1. Drain valve 11 in drain conduit 10 is shown closed and is opened when it is desired to drain fuel bowl 6.

In operation, the embodiment shown in FIG. 1 functions as follows. Starting with a cold engine, fuel selector switch 4 is set to open the flow path from volatile fuel tank 2 through fuel pump 5 to fuel bowl 6. Fuel selector valve 4 may be set manually, but is preferably positioned automatically in response to engine temperature. A temperature responsive bimetal switch can be used to signal valve actuating means to set fuel selector valve 4 to supply the proper fuel to fuel bowl 6 depending upon a predetermined engine temperature. The bimetal switch can be positioned to respond to engine temperature at any of several locations such as carburetor temperature, coolant temperature, oil temperature, or multiple bimetal switches can be used to respond to temperature at more than one location, thus requiring more than one location to attain a predetermined operating temperature before the circuit is com-

pleted to signal the valve actuating means to switch fuel selector valve 4 from one fuel to another. The predetermined temperature should be such that when the selector valve 4 is signalled to switch from delivering fuel from volatile fuel tank 2 to normal gasoline tank 1 the engine will operate smoothly with little, or preferably no, enrichment in the air/fuel ratio by means such as choking. This operating temperature need not be the final normal operating temperature of the engine but, rather, an intermediate temperature somewhere between the cold engine and the final normal operating temperature. The operating temperature at which selector valve 4 switches from volatile fuel to normal gasoline approximates the same temperature at which the well-known automatic choking in a conventional fuel system would be open because, in essence, the delivery of the volatile fuel replaces, or substantially replaces, the use of the choke.

When the engine starter is engaged, fuel pump 5 fills fuel bowl 6 with volatile fuel. This is delivered through fuel nozzle 12 to carburetor venturi 13 where it is mixed with air and inducted into the engine. By the use of the present fuel system, nozzle 12 delivers fuel at a leaner air/fuel ratio than would otherwise be required to start the engine using normal gasoline. For example, the engine can be started at air/fuel ratios of about 13–17:1 whereas conventional systems require a much richer ratio. Under very adverse conditions, such as very low temperature, only minimal enrichment may be required to allow the engine to start and operate smoothly during warm-up.

When the engine reaches an operating temperature at which it can operate smoothly on normal gasoline with little or no choking, selector valve 4 is switched such that it closes the path from volatile fuel tank 2 and opens the path from normal gasoline tank 1 such that fuel bowl 6 is supplied with normal gasoline. As mentioned above, this can be accomplished manually but is preferably accomplished automatically in response to engine temperature.

After the engine has operated using normal gasoline and is turned off fuel bowl 6 will contain residual normal gasoline. Once the engine cools it will not start and run smoothly of this residual normal gasoline without some enrichment of the air/fuel ratio—in other words, some choking would be required. To avoid this, fuel bowl 6 is preferably drained after each use so that on the next start-up the initial fuel supplied to the carburetor will be volatile fuel. This is accomplished by opening drain valve 11 allowing the residual normal gasoline in fuel bowl 6 to drain through drain conduit 10 to normal gasoline tank 1. Optionally, the fuel bowl could drain to some other container provided for that purpose. Opening of drain valve 11 can be accomplished manually but preferably it is made automatic. One method of accomplishing this is to provide valve actuating means such as an electrical solenoid which keep valve 11 closed when the engine electrical engine system is turned on and open valve 11 when the ignition system is turned off. By this means when the engine is again started, drain valve 11 will automatically close and either volatile fuel or normal gasoline will be delivered to fuel bowl 6 depending upon engine temperature.

Referring now to FIG. 2, another embodiment of the invention is shown in which a dual fuel carburetor 20 is provided which has a fuel bowl for normal gasoline

21 and a separate fuel bowl for volatile fuel 22. Selection of fuel delivered to carburetor venturi 23 is accomplished by interlocked valves 24 and 25. The interlocking provides that when one valve is open the other is closed. As shown, valve 25 is open and volatile fuel is being delivered to venturi 23 which would be the proper selection at engine start-up and warm-up. When the engine attains operating temperature, valve 25 is closed and valve 24 opens such that normal gasoline is delivered to venturi 23.

In FIG. 2 each of fuel bowls 21 and 22 have individual fuel delivery passages. In a similar arrangement the carburetor can be modified such that only a single fuel delivery passage through a main nozzle is provided for each venturi. This single nozzle is supplied with fuel from either the volatile fuel bowl or the normal gasoline bowl as required and the selection of which fuel is delivered to the single nozzle is controlled by valves in the fuel passage connecting the individual fuel bowls to the common nozzle. These valves function in a manner similar to valves 24 and 25.

Referring to FIG. 3, the normal gasoline is taken from the gasoline tank 38 by liquid fuel line 31 and enters the vaporizing means 32 where it is partially vaporized. The vapor and liquid are separated in vapor-liquid separator 33, which is connected by vapor-liquid line 34 to the vaporizing means 32. The vapor exits from vapor-liquid separator 33 via volatile fuel line 35, which connects with the fuel induction means (not shown) such as carburetor. The liquid which is depleted in volatile fuel components is discharged from the vapor-liquid separator means 33 via volatile-depleted fuel line 36 and according to automatically or manually predetermined conditions is either returned to the gasoline tank or delivered to the fuel induction means. The vapor-liquid separator 33 must operate under such conditions that the volatile fuel produced is substantially completely condensed. Thus, the vacuum drawn on the volatile fuel self-generating system by means of vacuum line 37 connected to the vaporizing means 32 through vapor-liquid separator 33 and to the engine is substantially free of vapor avoiding undue richness of the air/fuel mixture, fuel economy losses, and fuel metering problems.

From the foregoing it is readily apparent that a preferred embodiment of this invention is a method of separating normal gasoline into a volatile fraction and a portion depleted in volatile components by partially vaporizing said gasoline under vacuum, said vacuum being derived from the engine vacuum of a spark ignited internal combustion engine. The volatile fraction is then separated from the portion depleted in volatile components, i.e., the volatile depleted fuel, and the volatile fraction is used during a selected period of engine operation. To facilitate the production of the volatile fraction, the gasoline may be heated prior to vaporization. The amount of vacuum should be that required to vaporize from about 10 to about 50 weight percent of the normal gasoline. Operating under varying conditions, such as idle, normal cruising, and acceleration, engine vacuum can range from about 10 to about 21 inches of mercury or more depending on the particular engine. While any convenient source of engine vacuum may be used, for example, the carburetor venturi vacuum or intake manifold vacuum, the latter is preferred. The portion depleted in volatile components need not be completely depleted but the separation should be

such that a major portion of the volatile components in normal gasoline are vaporized and separated in the vapor-liquid separator.

It should also be clear that the vapor-liquid separator 33 of FIG. 3 may include a condenser which is slightly efficient, liquefying the volatile portion substantially completely such that a liquid seal is maintained between the engine vacuum source and the vaporizing means. This may be accomplished, without limiting the invention, by using refrigeration to obtain substantially complete condensation of the vapor. For the amount and composition of volatile fuel produced if from about 10 to about 50 weight percent of the normal gasoline, the volatile fuel would condense at a temperature from about 30 to about 50°F. A convenient source of refrigeration in an automobile is the air-conditioning system if available. A person of ordinary skill in the art can suggest the necessary arrangement of means to connect the condenser to the automobile air-conditioning system. Other mechanical refrigeration systems using either vapor-compression machines having positive-displacement compressors, such as reciprocating, rotary, or centrifugal compressors, steam jets or continuous or intermittent absorption systems using, for example, ammonia or lithium bromide as the refrigerant are typical.

The condenser is connected to a vacuum chamber which acts as a collector for the condensate. The vacuum chamber has an upper section which is essentially free vacuum, assuming that the condenser has substantially completely liquefied the vapor and a lower section which collects the condensate. The lower section can be connected to a suitable pump which advances the condensate into a volatile fuel storage container. The upper section is connected by vacuum line to the source of engine vacuum. The volatile fuel generation system is preferably operated when the vapor is completely condensed. This prevents the vapor from entering the engine vacuum causing fuel metering problems, unnecessarily rich engine operation and penalizing fuel economy. However, a small non-condensable fraction would not significantly affect operation of the engine.

Referring to FIG. 4, a preferred embodiment of the invention is a system for self-generation of a volatile fuel including a liquid fuel conduit 42 connected to the gasoline tank 46C and to expansion valve 41 through pump 44C and heater 40 in heat exchange relationship with conduit 42 and adapted to heat the liquid fuel in conduit 42. Expansion valve 41 is connected to vaporizing chamber 43 which has vapor conduit 44 connected to the vapor discharge outlet, volatile-depleted fuel conduit 46 connected to the liquid discharge outlet and a vent line 45B in which is located relief valve 45A. Volatile-depleted fuel line 46 connects to gasoline tank 46C through pump 47 and one-way check valve 42C. Pump 47 is actuated by liquid-level switch 40C in vaporizing chamber 43, employing actuating means 41C. Located in vapor conduit 44 is one-way check valve 45 which maintains flow in one direction only through vapor conduit 44 to the inlet of condenser 48. Condenser 48 can conveniently be connected to the automobile air-conditioning system (not shown) or any suitable refrigeration means (not shown) to substantially completely condense the volatile fuel. The outlet of condenser 48 is connected to vacuum chamber 49 which has upper and lower sections. The lower section of vacuum chamber 49 is connected to volatile fuel

storage tank 40A by means of liquid fuel conduit 43C containing pump 41A and one-way check valve 42A. The upper section of vacuum chamber 49 communicates with a source of engine vacuum by vacuum line 49A in which is located valve 49B. Also, the upper section of vacuum chamber 49 has vent line 46B in which is located pressure relief valve 46A and connects with the gasoline tank 46C or a suitable absorption system (not shown).

The volatile fuel storage container 40A has in addition to liquid fuel conduit 43C from vacuum chamber 49, a liquid-level switch 43A connected by actuating means 43B to valve 49B, liquid fuel conduit 44A in which is located pressure regulating valve 45C for delivery of volatile fuel to the carburetor (not shown), and vent line 47B having pressure relief valve 47A. The vent line is connected to the gasoline tank 46C or any suitable absorption system (not shown). If necessary, an auxiliary fuel pump may be inserted in conduit 44A.

In operation the volatile fuel self-generation system of this preferred embodiment produces a volatile fuel from normal gasoline in which normal gasoline from the gasoline tank 46C is fed through liquid fuel line 42 by pump 44C to expansion valve 41 and is heated by means of heater 40 located in heat exchange relationship with liquid fuel line 42. The heater 40 may be an electrically operated resistance heating coil wrapped around fuel line 42 or any other suitable means for heating may be employed. The heater should be adapted to bring the fuel to a temperature high enough to facilitate vaporization when passed through expansion valve 41. For best results the temperature should be from about 150°F to about 275°F and preferably from about 175°F to about 250°F. The amount of fuel vaporized depends both on temperature and pressure and the two are not independent variables. For best vaporization, conditions should be set experimentally for each particular engine. Typical examples of suitable heaters are heat exchangers using hot engine coolant, direct or indirect gas-fired heaters or the like. The expansion valve 41 may be a pressure responsive valve allowing passage and partial vaporization of liquid fuel delivered to it in response to a predetermined pressure differential caused by application of engine vacuum and pressure from pump 44C. The pressure level of expansion valve 41 should be set at a level to obtain the desired vaporization in relation to the valve pressure can adapted vacuum. For best results the pressure should not be less than about 30 psig and preferably the expansion valve should be set for about 60 psig. The vapor-liquid mixture passes into a vaporizing chamber 43 where the vapor is drawn into vapor conduit 44 through one-way check valve 45 in response to the decreased pressure caused by the engine vacuum. The liquid separated from the vapor and depleted in volatile fuel components is collected and drained from the vaporizing chamber 43 through volatile-depleted fuel line 46, and pump 47 responding to liquid-level switch 40C, pumps the volatile depleted fuel from vaporizing chamber 43 into the gasoline tank 46C through one-way check valve 42C by means of conduit 46. Volatile-depleted fuel line 46 can be adapted to return the volatile-depleted fuel to the gasoline tank 46C or with appropriate valving can be adjusted to deliver fuel to the carburetor or separate storage.

The vapor in vapor conduit 44 is delivered to the condenser 48 adapted to substantially completely con-

dense the vapor thus producing the volatile fuel. The complete condensation prevents the vapor from entering the vacuum source, which is the engine vacuum, upsetting fuel/air mixtures and lowering fuel economy.

As described above, a preferred embodiment of the condenser 48 is a refrigeration unit such as those used for an automotive air-conditioning unit. The condensate is conducted into vacuum chamber 48 where the liquid volatile fuel is collected in the lower section for delivery by liquid volatile fuel conduit 43C to the volatile fuel storage tank 40A by means of pump 41A through one-way check valve 42A. The pump 41A can conveniently be controlled by a conventional liquid-level controller (not shown) which is connected through the side wall of vacuum chamber 49. The upper section of vacuum chamber 49 is maintained under vacuum by means of vacuum line 49A when vacuum valve 49B is in the open position and engine vacuum is drawn on the system.

The opening or closing of vacuum valve 49B is controlled by the liquid-level switch 43A in volatile fuel storage tank 40A and signals the vacuum valve 49B through actuating means 43B. When the amount of liquid volatile fuel falls below a predetermined level, the switch 43A signals vacuum valve 49B via actuating means 43B, the valve is opened and engine vacuum is drawn on the system causing vaporization of the normal gasoline to produce more volatile fuel. The liquid level in volatile fuel storage tank 40A should be high enough to allow sufficient volatile fuel for cold start and warm-up operations.

From the volatile fuel storage tank 40A the liquid volatile fuel is delivered to the engine fuel induction means (not shown), such as a conventional carburetor, by liquid fuel conduit 44A. Valve 45C passes the liquid volatile fuel from the volatile fuel storage tank by conduit 44A to the carburetor. A valve switching arrangement as described in FIG. 5, but not shown here, determines when volatile fuel is delivered to the carburetor.

For safety purposes relief valves 45A, 46A, and 47A are located in vent lines 45B, 46B, and 47B, respectively, which are attached to the vaporizing chamber 43, vacuum chamber 49, and volatile fuel storage tank 40A, respectively. The vent lines can be connected to the gasoline tank 46C or any other suitable vapor absorption system used on the automobile.

From the foregoing description of FIG. 4, it can be seen that a preferred embodiment of this invention is in a fuel system which feeds gasoline and a volatile gasoline fraction to a spark ignited internal combustion engine during selected periods of engine operation, the improvement comprising

- a. a vacuum line connected at one end to a source of engine vacuum,
- b. a vaporizing chamber connected by a liquid fuel line to a gasoline tank,
- c. a vacuum chamber connected to the other end of said vacuum line, and
- a vapor conduit connecting said vaporizing chamber with said vacuum chamber. In another more preferred embodiment of the above fuel system, the vaporizing chamber is pressure responsive whereby a portion of said gasoline delivered to said chamber through said liquid fuel line is vaporized in response to a predetermined pressure drop from said liquid fuel line to said vaporizing chamber caused by said engine vacuum. Another more preferred

embodiment of the above fuel system has heating means in heat exchange relationship with said liquid fuel line whereby said gasoline is heated prior to entering said vaporizing chamber. Another preferred embodiment of this invention has a condensing means in said vapor conduit whereby the vapor produced from said gasoline in said vaporizing chamber is substantially completely condensed, producing a liquid volatile gasoline fraction. In another preferred embodiment the vacuum chamber comprises a lower section for collecting the condensate and an upper section communicating with said engine vacuum source by said vacuum line whereby the upper section of said vacuum chamber is maintained under vacuum during operation of said fuel system to produce said volatile gasoline fraction. A most preferred embodiment has in the vacuum chamber a pervious vapor-liquid impingement separator means whereby said condensate is separated from any uncondensed vapor. In another most preferred embodiment of this invention the fuel system has

- a. a heater in heat exchange relationship with said liquid fuel line whereby said gasoline is heated prior to entering said vaporizing chamber thereby facilitating vaporization,
- b. a pressure responsive valve means connected to said liquid fuel line and downstream of said heater, whereby a portion of said gasoline is vaporized in response to a predetermined pressure drop across said valve from the upstream side of said valve to the downstream side of said valve caused by said engine vacuum, and
- c. a volatile fuel storage tank having an inlet connected to said vacuum chamber through pump means and one-way check valve means, an outlet connected by a liquid volatile fuel conduit to the fuel induction means of said engine, pressure relief valve means adapted to open on reaching a predetermined pressure, and pressure regulating valve means in said liquid volatile fuel conduit adapted to deliver liquid volatile fuel to said fuel induction means at a preset pressure.

Referring to FIG. 5, a preferred embodiment of the invention is shown in which the volatile fuel self-generation system of FIG. 4 is connected to a spark ignited internal combustion engine. FIG. 5 shows a normal gasoline tank 50 connected to the volatile fuel self-generation system and also directly to the engine. A fuel switching arrangement is provided to alternately deliver the normal gasoline or the volatile gasoline fraction to the fuel induction means, for example a carburetor, during selected periods of engine operation. The normal gasoline tank 50 is connected to fuel inlet 52 of the carburetor by liquid fuel conduit 51 in which is located fuel pump 53 and fuel selector valve 54. A second liquid fuel conduit 55, connected to line 51 between pump 52 and valve 54, connects gasoline tank 50 through heater 59C and expansion valve 56 to vaporizing chamber 57. Vaporizing chamber 57 is connected through its top end closure by vapor conduit 58 through one-way check valve 59 to the inlet of condenser 50A. The outlet of condenser 50A connects to vacuum chamber 51A through volatile fuel conduit 50B. Vacuum chamber 51A connects through its top end closure to the engine intake manifold 52A by means of vacuum conduit 54A in which valve 55A is

located. In the event that the vapor is not completely condensed in condenser 50A, vacuum chamber 51A can also contain a vapor-liquid impingement separator to completely separate the liquid volatile fuel from said vapor. The use of a vapor-liquid separator would prevent the vapor from carrying entrained liquid volatile fuel with it into the engine vacuum. Vacuum chamber 51A is also connected through its bottom end closure by liquid volatile fuel conduit 53D to volatile fuel storage tank 56A through pump 57A and one-way check valve 58A. The bottom of volatile fuel storage tank 56A is connected by volatile fuel conduit 59A through fuel selector valve 52B to the fuel inlet 52 of the carburetor. Located in conduit 59A is pump 51B. The top of volatile fuel storage tank 56A is connected through pressure relief valve 53B by a second vapor conduit 54B back to the gasoline tank 50.

The vacuum chamber 51A is also connected through its top end closure by a vapor 55B through pressure relief valve 56B to the gasoline tank 50. Vaporizing chamber 57 is connected through its top end closure to gasoline tank 50 by a vapor conduit 57B having pressure relief valve 58B.

Vaporizing chamber 57 connects through its bottom end to the gasoline tank 50 through volatile-depleted fuel conduit 59B having located therein pump 52D and one-way check valve 50C. Located in vaporizing chamber 57 is liquid-level switch 51C which is connected to pump 52D by actuating means 51D and is adapted to close volatile-depleted fuel line 59B.

Drain conduit 52C connects a drain outlet at the bottom of the carburetor fuel bowl such as drain 9 in FIG. 2 through valve 53C to fuel conduit 51 between gasoline tank 50 and fuel pump 53.

Bimetal thermal switch 54C is connected by actuating means 55C and 56C to valves 52B and 54 respectively.

Located inside volatile fuel storage tank 56A is liquid-level switch 57C which connects through the side wall of tank 56A by actuating means 58C to a valve 55A.

In operation starting with a cold engine turning the ignition on causes drain valve 53C to close. Thermal switch 54C responding to the low engine temperature has valve 52B in an open position and valve 54 in a closed position. Volatile gasoline fraction from volatile fuel storage tank 56A is delivered through conduit 59A by pressure regulating valve 51B in response to conventional signalling means, such as by a standard float actuated fuel bowl valve and fills the fuel bowl of the carburetor. Actuating the starter starts the engine which operates without choking using the volatile gasoline fraction.

After 2 to 3 minutes of operation the liquid engine coolant temperature rises to a predetermined level at which experience has shown the particular engine can operate on normal gasoline without choking. Thermal switch 54C senses this temperature and actuates valve 52B to close and valve 54 to open. During continued operation, normal gasoline is supplied to the carburetor from gasoline tank 50 through fuel conduit 51.

Assuming the liquid level in volatile fuel storage tank 56A has dropped below a predetermined level (which level should provide sufficient reserve volatile fuel to start and warm-up the engine), liquid-level actuated switch 57C closes and by actuating means 58C opens valve 55A. A vacuum from the engine manifold 52A is

drawn on the volatile fuel generation system which operates in the manner described in FIG. 4.

Therefore, it can be seen that without limiting the invention, the foregoing description provides a preferred embodiment of another aspect of the invention which is in a fuel system for feeding gasoline and a volatile gasoline fraction to a spark ignited internal combustion engine, comprising means for delivering gasoline to the fuel induction means, means for delivering a volatile gasoline fraction to said fuel induction means, fuel switching means adapted to deliver said volatile gasoline fraction to said fuel induction means during a selected period of engine operation, and self-generation means for producing said volatile gasoline fraction by vaporizing a portion of said gasoline in a vaporizing chamber, separating the vapor and condensing said vapor to form said volatile gasoline fraction, the improvement comprising engine vacuum means connected by a vacuum conduit to said self-generation means, vacuum valve means connected in said vacuum conduit between said vacuum means and said self-generation means, and means to signal said vacuum valve means to open causing a reduction in pressure in said vaporizing chamber of said self-generation means to produce said volatile gasoline fraction and to close causing the production of said volatile gasoline fraction to cease.

In a most preferred embodiment of the above fuel system the vacuum means is the engine intake manifold of said engine. In another preferred embodiment of the invention is the fuel system above having in said self-generation means a container for said volatile gasoline fraction connected by a volatile liquid fuel conduit to said fuel induction means. A still further preferred embodiment of the invention is the fuel system above wherein said vacuum valve means is controlled by a liquid-level sensing means in said container for said volatile gasoline fraction whereby at a liquid level below a predetermined level said liquid-level sensing means causes said vacuum valve to open which causes a reduction in pressure in said vaporizing chamber resulting in the vaporization of a portion of said gasoline producing said volatile gasoline fraction and at a liquid level above a predetermined level said liquid-level sensing means causes said vacuum valve to close which causes the production of said volatile gasoline fraction to cease.

I claim:

1. In a fuel system which feeds gasoline and a volatile gasoline fraction to a spark ignited internal combustion engine during selected periods of engine operation, the improvement comprising a vacuum line connected at one end to a source of engine vacuum, a vaporizing chamber connected by a liquid fuel line to a gasoline tank, a vacuum chamber connected to the other end of said vacuum line, said vacuum chamber comprising a lower section for collecting the condensate and an upper section communicating with said engine vacuum source by said vacuum line whereby the upper section of said vacuum chamber is maintained under vacuum during operation of said fuel system to produce said volatile gasoline fraction, said vacuum chamber having a pervious vapor-liquid impingement separator means whereby said condensate is separated from any uncondensed vapor, a vapor conduit connecting said vaporizing chamber with said vacuum chamber, condensing means in said vapor conduit whereby the vapor pro-

duced from said gasoline in said vaporizing chamber is substantially completely condensed, producing a liquid volatile gasoline fraction, a heater in heat exchange relationship with said liquid fuel line whereby said gasoline is heated prior to entering said vaporizing chamber thereby facilitating vaporization, a pressure responsive valve means connected to said liquid fuel line and downstream of said heater, whereby a portion of said gasoline is vaporized in response to a predetermined pressure drop across said valve from the upstream side of said valve to the downstream side of said valve caused by said engine vacuum, and a volatile fuel storage tank having an inlet connected to said vacuum chamber through pump means and one-way check valve means, an outlet connected by a liquid volatile fuel conduit to the fuel induction means of said engine, pressure relief valve means adapted to open on reaching a predetermined pressure, and pressure regulating valve means in said liquid volatile fuel conduit adapted to deliver liquid volatile fuel to said fuel induction means at a preset pressure.

2. In a fuel system which feeds gasoline and a volatile gasoline fraction to a spark ignited internal combustion engine during selected periods of engine operation, the improvement comprising

- a. a vacuum line connected at one end to a source of engine vacuum,
- b. a vaporizing chamber connected by a liquid fuel line to a gasoline tank,
- c. a vacuum chamber connected to the other end of said vacuum line,
- d. a vapor conduit connecting said vaporizing chamber with said vacuum chamber,
- e. a heater in heat exchange relationship with said liquid fuel line whereby said gasoline is heated prior to entering said vaporizing chamber thereby facilitating vaporization,
- f. a pressure responsive valve means connected to said liquid fuel line and downstream of said heater, whereby a portion of said gasoline is vaporized in response to a predetermined pressure drop across said valve to the downstream side of said valve caused by said engine vacuum, and
- g. a volatile fuel storage tank having an inlet connected to said vacuum chamber through pump means and one-way check valve, an outlet connected by a liquid volatile fuel conduit to the fuel induction means of said engine, pressure relief valve means adapted to open on reaching a predetermined pressure, and pressure regulating valve means in said liquid volatile fuel conduit adapted to deliver liquid volatile fuel to said fuel induction means at a preset pressure.

3. In a fuel system which feeds gasoline and a volatile gasoline fraction to a spark ignited internal combustion engine during selected periods of engine operation, the improvement comprising

- a. a vacuum line connected at one end to a source of engine vacuum;
- b. a vaporizing chamber connected by a liquid fuel line to a gasoline tank;
- c. a vacuum chamber connected to the other end of said vacuum line, said vacuum chamber comprising a lower section for collecting the condensate and an upper section communicating with said engine vacuum source by said vacuum line whereby the upper section of said vacuum chamber is main-

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- tained under vacuum during operation of said fuel system to produce said volatile gasoline fraction;
- d. a vapor conduit connecting said vaporizing chamber with said vacuum chamber;
- e. a heater in heat exchange relationship with said liquid fuel line whereby said gasoline is heated prior to entering said vaporizing chamber thereby facilitating vaporization; 5
- f. a pressure responsive valve means connected to said liquid fuel line and downstream of said heater, whereby a portion of said gasoline is vaporized in response to a predetermined pressure drop across said valve from the upstream side of said valve to 10

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- the downstream side of said valve caused by said engine vacuum; and
- g. a volatile fuel storage tank having an inlet connected to said vacuum chamber through pump means and one-way check valve means, an outlet connected by a liquid volatile fuel conduit to the fuel induction means of said engine, pressure relief valve means adapted to open on reaching a predetermined pressure, and pressure regulating valve means in said liquid volatile fuel conduit adapted to deliver liquid volatile fuel to said fuel induction means at a preset pressure. 15
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UNITED STATES PATENT OFFICE  
CERTIFICATE OF CORRECTION

Patent No. 3,783,849 Dated January 8, 1974

Inventor(s) Thomas Hugh Bramfitt

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 6, line 67, reads "fuel carburetor", should read -- fuel bowl carburetor --. Col. 7, line 10, the following paragraph was omitted:

"Valves 24 and 25 can be operated manually but are preferably coupled with the previously-described engine temperature sensing bimetal switch which was used to actuate valve 4 in Figure 1. In this manner, valve 25 will be automatically opened on start and warm-up. When the engine attains smooth operating temperature, valve 25 will automatically close and valve 24 will open. Valves 24 and 25 are also interlocked with valve 26 in normal gasoline conduit 27 and valve 28 in volatile fuel conduit 29 such that when valve 25 is open valve 28 is open and valves 24 and 26 are closed. Likewise, when the engine attains operating temperature and valve 24 opens, valve 26 also opens and valves 25 and 28 close."

Col. 7, line 64, reads "engie", should read -- engine --. Col. 8, line 5, reads "slightly", should read -- highly --. Col. 9, line 47, delete "valve pressure can adapted vacuum", and insert -- engine vacuum. --. Col. 9, line 53, reads "vlve", should read -- valve --. Col. 9, line 54, reads "ressure", should read -- pressure --. Col. 9, line 64, reads "cna be adjusted", should read -- can be adapted --. Col. 10, line 8, reads "48", should read -- 49 --. Col. 10, line 60, add "d.". Col. 11, line 59, reads "pump 52", should read -- pump 53 --. Col. 12, line 19, reads "vapor 55B", should read -- vapor conduit 55B --. Col. 12, line 34, reads "2", should read -- 1 --. Col. 13, line 32, reads "menas", should read -- means --. Col. 13, line 65, reads "sid", should read -- said --. Col. 14, line 7, reads "mans", should read -- means --. Col. 14, line 47, reads "valve, an", should read -- valve means, an --.

Signed and sealed this 19th day of November 1974.

(SEAL)  
Attest:

McCOY M. GIBSON JR.  
Attesting Officer

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