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Hutchinson

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[54] **PROCESS AND APPARATUS USING CIRCULATING GAS STRIPPING LOOP FOR ON-BOARD PRODUCTION OF VOLATILE FUEL TO OPERATE AN INTERNAL COMBUSTION ENGINE**

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[52] **U.S. Cl.** .... **123/3,** 123/127, 123/133, 123/134, 123/179 G

[51] **Int. Cl.** **F02b 43/08,** F02m 13/04

[58] **Field of Search** .... 123/127, 2, 3, 179 G, 133, 123/13 A; 196/98, 104; 208/350, 359, 361, 366

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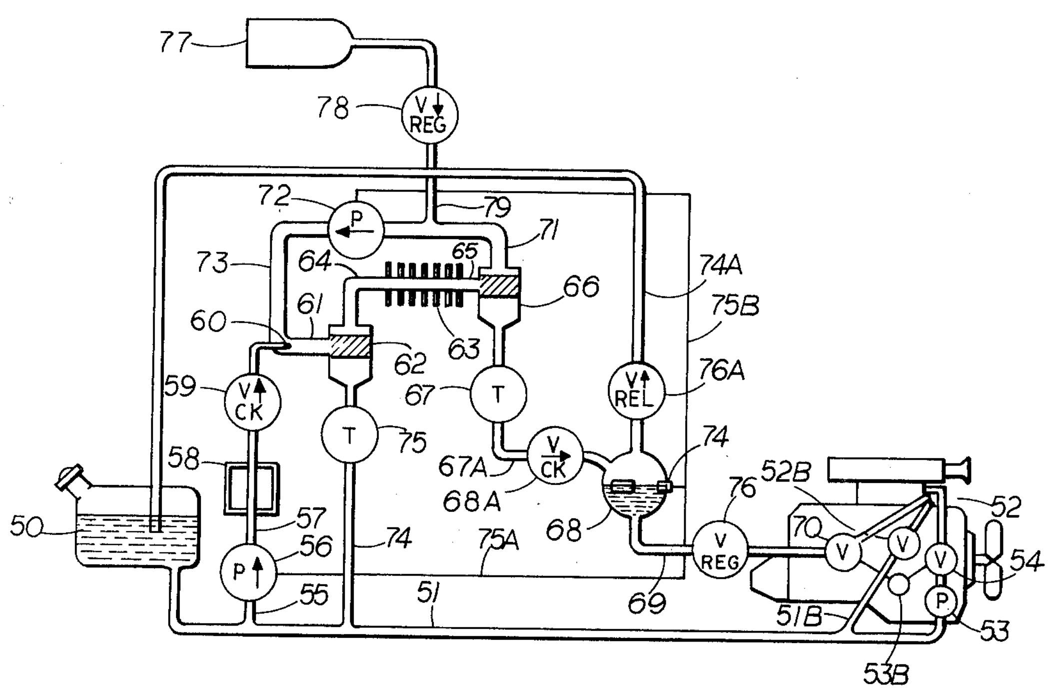
[57] **ABSTRACT**

An improved fuel system containing a circulating inert gas stripping loop including means to partially vaporize gasoline, condense the vapor to obtain a volatile fuel for use in start and warm-up of an internal combustion gasoline engine, and recirculate the inert gas. A dual liquid fuel system for an internal combustion engine equipped with a single fuel metering system, means to deliver a volatile fuel to the carburetor or other fuel metering means on start-up and until the engine attains a predetermined operating temperature and fuel switching means to deliver normal gasoline for warmed-up operation is disclosed.

16 Claims, 5 Drawing Figures



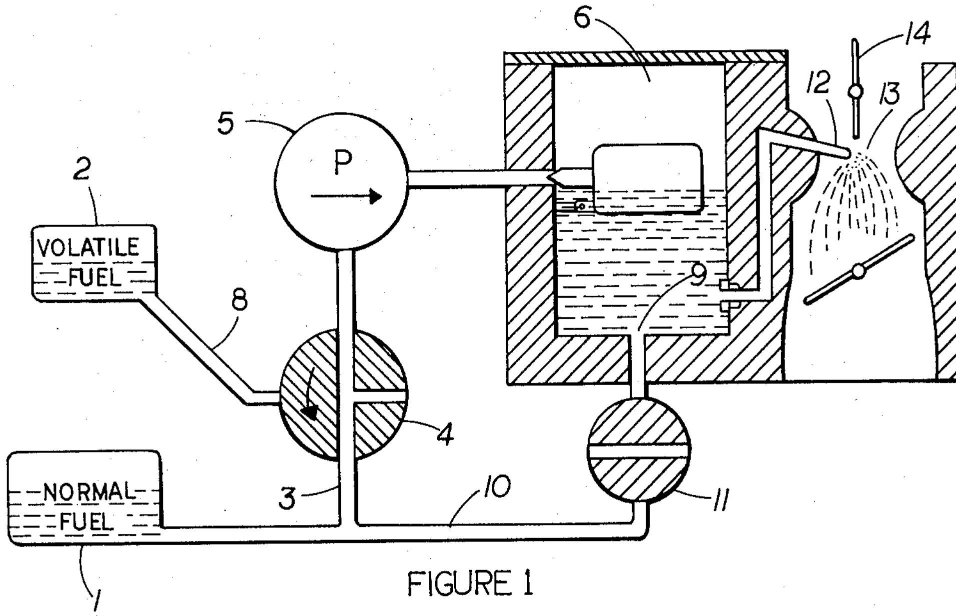


FIGURE 1

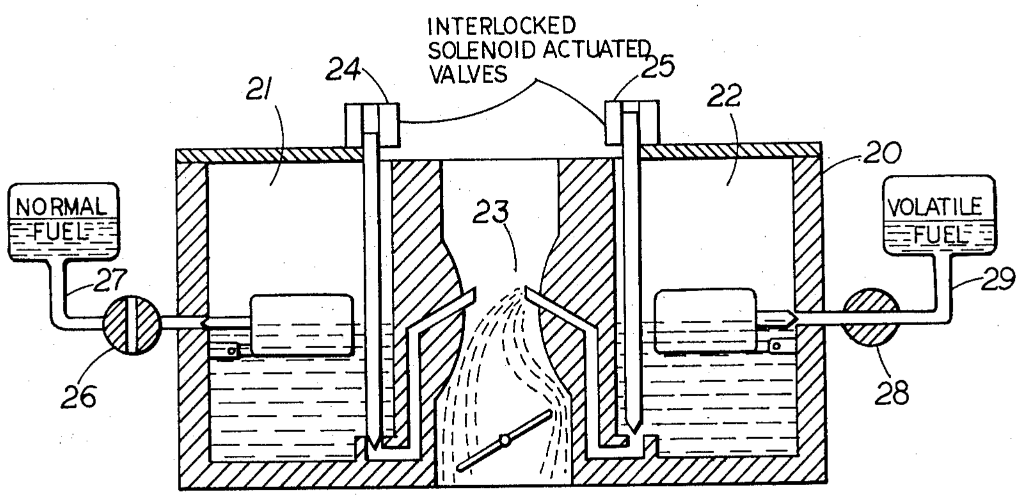


FIGURE 2

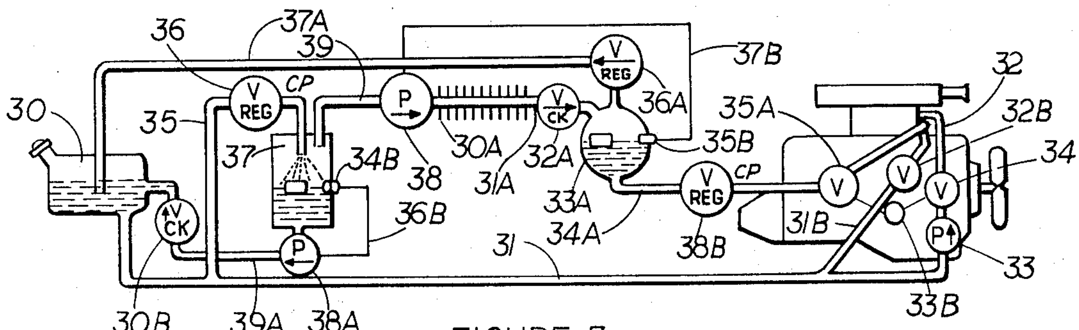


FIGURE 3

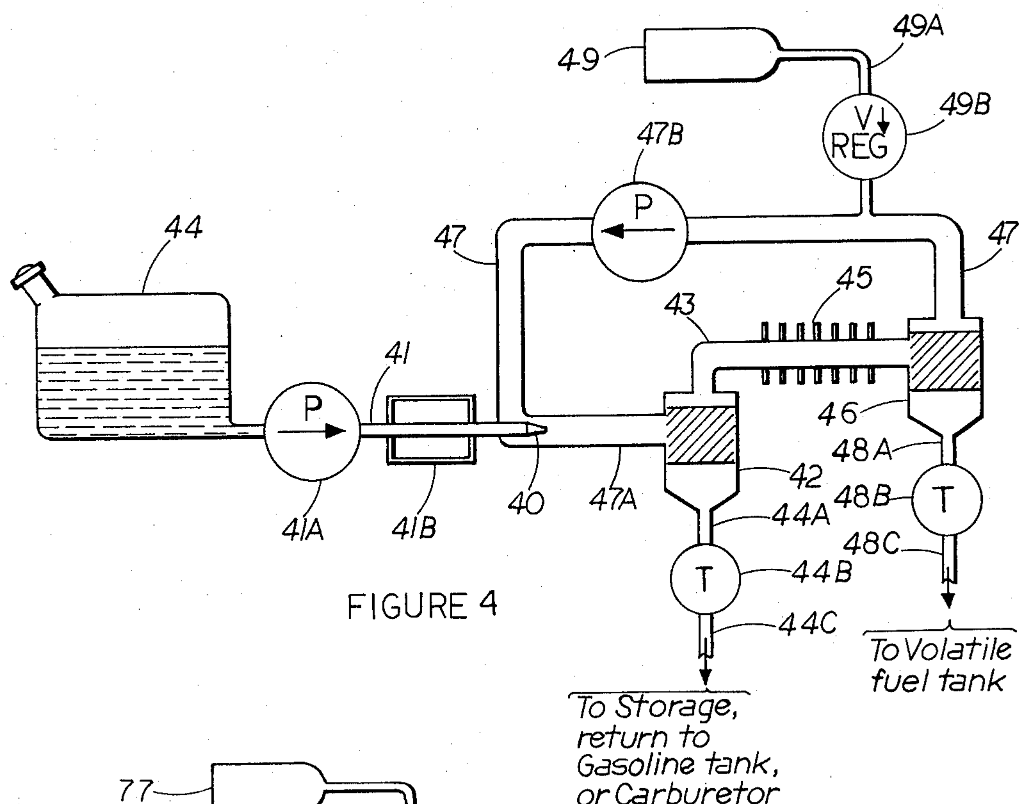


FIGURE 4

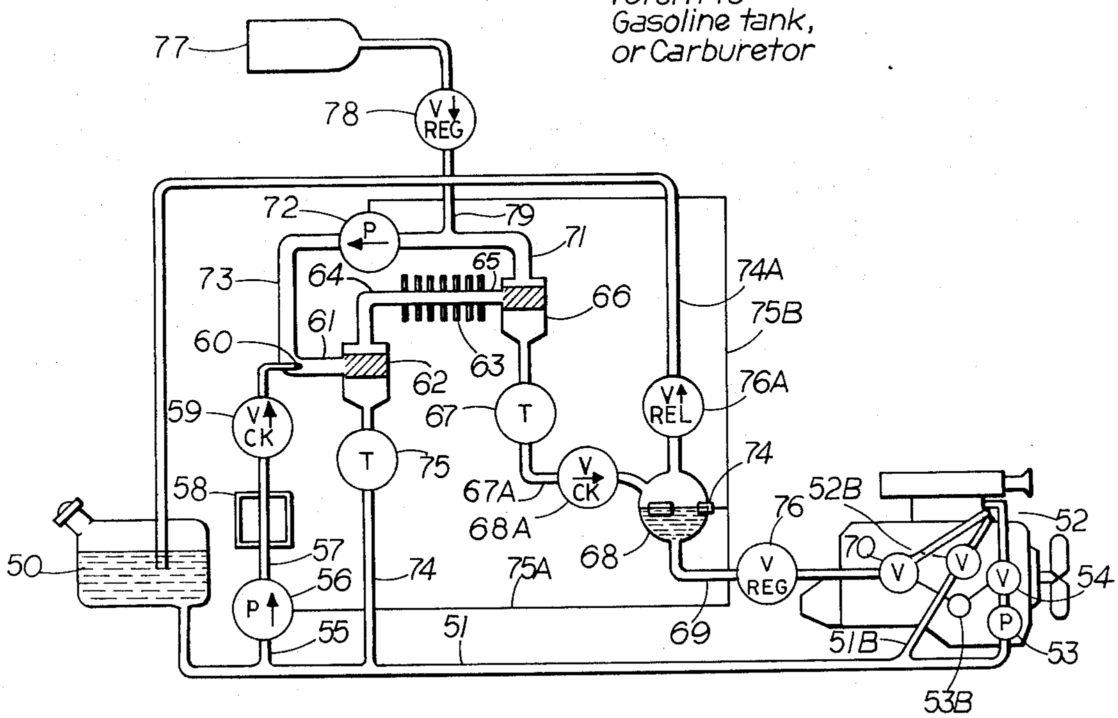


FIGURE 5

PROCESS AND APPARATUS USING CIRCULATING GAS STRIPPING LOOP FOR ON-BOARD PRODUCTION OF VOLATILE FUEL TO OPERATE AN INTERNAL COMBUSTION ENGINE

BACKGROUND OF THE INVENTION

The exhaust gas of internal combustion engines contains various amounts of unburned hydrocarbons, carbon monoxide, and nitrogen oxides (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 modification, 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 ten per cent 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 and a 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 dual 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 above and further objects are accomplished by providing a gas stripping loop including means for mixing an inert gas with a liquid hydrocarbon fuel of the gasoline boiling range to partially vaporize the volatile portion of this fuel, a vapor-liquid separating means to remove the gas containing the vapor from the residual liquid, means to condense the vapor whereby a liquid hydrocarbon fuel of the lower gasoline boiling range is formed, a second vapor-liquid separating means to remove the gas from the liquid hydrocarbon fuel of the lower gasoline boiling range, and means to recirculate the gas to the mixing means for further vaporization.

In a preferred embodiment, the temperature and pressure of the liquid hydrocarbon fuel are raised by pumping and heating means to facilitate vaporization and recovery of a volatile portion of the fuel. The pressure of the entering fuel should be raised to about 20–100 psia and the temperature should be 25°–75° F higher than the temperature of the vapor condenser wherein the more volatile fuel is formed. The recirculation of the inert stripping gas is accomplished by a pump connected in a vapor circuit from the second vapor-liquid separator and discharging to the mixing means. The vapor-liquid separators are preferably sized to handle the vapor flow rate established by the inert stripping gas pump and effect substantially complete separation between the vapor and liquid. In another preferred embodiment the circulating gas stripping loop of this invention is included in a dual liquid fuel system for a spark ignited internal combustion engine having a single fuel metering system comprising means for delivering liquid hydrocarbon fuel of the gasoline boiling range to the fuel induction means, means for delivering liquid hydrocarbon fuel of the lower gasoline boiling range to the fuel induction means, and fuel switching means adapted to deliver the liquid hydrocarbon fuel of the lower gasoline boiling range to the fuel induction means during a selected period of engine operation. The use of the circulating gas stripping loop of this invention provides an advantageous method of producing the volatile fuel from the normal gasoline on board.

In another preferred embodiment of this invention, there is provided an improved method of operating a spark ignited internal combustion engine adapted to reduce noxious exhaust emission comprising delivering a liquid hydrocarbon fuel of the lower gasoline boiling range to the carburetor or other fuel induction means of the engine during start and warm-up and delivering liquid hydrocarbon fuel of the normal gasoline boiling range to the carburetor or other fuel induction means after the engine has attained a normal or near normal operating temperature. The improvement comprises generating the liquid hydrocarbon fuel of the lower gasoline boiling range from the liquid hydrocarbon fuel of the normal gasoline boiling range by mixing therewith a substantially inert gas whereby a portion of the liquid hydrocarbon fuel of the gasoline boiling range is vaporized, separating the gas containing the vapor from the residual fuel which is now less volatile, or depleted in volatile components, condensing the vapor from the gas to produce a liquid hydrocarbon fuel of the lower gasoline boiling range, separating this fuel from the inert gas, and recirculating the gas to the mixer with the liquid hydrocarbon fuel of the lower gasoline boiling range being delivered to a container for subsequent use during start and warm-up of the engine. Preferably, the mixing is carried out in a mixing nozzle designed to intimately contact the inert gas with the liquid hydrocarbon fuel of the gasoline boiling range. Circulation for the gas stripping loop is provided by having a pump located in the gas stripping loop. Another preferred embodiment is to pressurize and heat the liquid hydrocarbon fuel to the preferred operating conditions by using a suitable pump and a heat exchanger in series. This treatment will facilitate vaporization of a portion of the liquid hydrocarbon fuel of the gasoline boiling range. A preferred condensing arrangement is condensing the volatile fuel in an air-cooled, finned-tube condenser.

Broadly, however, in a spark ignited internal combustion engine, the invention is a method of producing a volatile fuel from a liquid hydrocarbon fuel of the gasoline boiling range comprising vaporizing a portion of the liquid hydrocarbon fuel of the gasoline boiling range and separating the vapor for use during a selected period of engine operation. Preferably, the vaporizing is carried out by contacting the liquid hydrocarbon fuel of the gasoline boiling range with a stripping gas. In a preferred embodiment the vapor produced is compressed, producing a liquid hydrocarbon fuel of the lower gasoline boiling range and separating the stripping gas from the liquid hydrocarbon fuel of the lower gasoline boiling range. A still further preferred embodiment calls for heating the liquid hydrocarbon fuel of the gasoline boiling range prior to contacting with the stripping gas. In a still further preferred embodiment the stripping gas is recycled to the contacting step after separation from the liquid hydrocarbon fuel of the lower gasoline boiling range.

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 tha 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 of the dual liquid fuel system showing its connection to a carburetor on an internal combustion gasoline engine. Also shown is an automatic fuel vaporizer and finned-tube condensing system for self-generation of the volatile fuel supply. The drawing also shows liquid level controls in the vaporizer and in the volatile fuel container which function to actuate pumps which control the liquid level in the vaporizer and volatile fuel container. Also shown are valves in the two fuel delivery conduits for switching from one fuel to the other. Also included is a valved drain line from the carburetor to the normal gasoline tank permitting drain of residual fuel when the engine is turned off.

FIG. 4 is a schematic of an improved vaporizing system showing a circulating gas stripping loop including a pump and heater to bring the liquid hydrocarbon fuel to the desired conditions, a mixing nozzle for vaporizing a portion of the fuel, a vapor-liquid separator to remove the residual liquid, a condenser for liquefying the vapor to produce the volatile fuel, and a second vapor-liquid separator for removing the volatile fuel with the non-condensable circulating gas being recycled to the mixing valve.

FIG. 5 is a schematic of a dual liquid fuel system showing the connection of the improved vaporizing system of FIG. 4 to the fuel system of an internal combustion engine, including the gasoline tank and connections to the carburetor. Also shown is a liquid level sensor in the volatile fuel storage container for activating the circulating gas stripping loop. Also shown is a heater adjacent the normal gasoline fuel line for increasing the efficiency of the volatilizing system. Also shown are valves in the dual liquid fuel delivery conduits for switching from one fuel to the other. Also included is a valved drain line from the carburetor to the gasoline tank permitting drainage of residual fuel when the engine is turned off.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, a preferred embodiment of the invention is a dual liquid fuel delivery system for a gasoline operated spark ignited internal combustion engine having a gasoline tank 1 for liquid hydrocarbon fuel of the gasoline boiling range (referred to hereafter as normal gasoline) and a container for liquid hydrocarbon fuel of the lower gasoline boiling range 2 (referred to hereafter as volatile fuel).

Liquid hydrocarbon fuels of the gasoline boiling range are mixtures 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 eydrocarbons 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_4 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 per cent, an olefinic hydrocarbon content ranging from 0 to about 30 volume per cent, and a saturate hydrodcarbon content ranging from about 40 to 80 volume per cent, 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 reformate, or the like), alkylate (e.g., C_{6-9} saturates made by reacting C_4 olefins with isobutane using a HF or H_2SO_4 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(β-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 volatile fuel, are hydrocarbons 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 dual 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 dual 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 dual 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 dual fuel system of this invention.

The optimum final boiling point for the volatile fuel to be used in the dual 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 fuel is from about 60°–300° F. Especially good results are obtained in most applications using a volatile fuel 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, further embodiments of this invention, to be described in detail hereafter, include in the dual liquid fuel system means for removing the light ends from normal gasoline and using these as the volatile fuel 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 **2**, **3**, or **4** 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 fuel 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 valve **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 completed 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 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 on 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 bowl carburetor **20** is 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**.

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 activate valve **4** in FIG. **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.

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**.

FIG. **3** shows the dual fuel system connected to an internal combustion engine having carburetor fuel metering means. The system includes an integral self-generation unit for obtaining volatile fuel from normal gasoline. Gasoline tank **30** is connected by liquid fuel conduit **31** to fuel inlet **32** of the carburetor. In fuel conduit **31** is fuel pump **33** and fuel selector valve **34**. A second liquid fuel conduit **35** connects gasoline tank **30** through one-way pressure regulating valve **36** to the top of vaporizing chamber **37** which is formed by a substantially cylindrical side wall and end closures. Vaporizing chamber **37** is connected to the inlet of vapor compressor **38** by vapor conduit **39** entering vaporizing chamber **37** through the top end closure. The outlet of compressor **38** is connected to the inlet of finned-tube condenser **30A**. The outlet of condenser **30A** is connected by volatile fuel condensate conduit **31A** through one-way check valve **32A** to spherical volatile fuel tank **33A**. The bottom of volatile fuel tank **33A** is connected by volatile liquid fuel conduit **34 A** through fuel selector valve **35A** to the fuel inlet **32** of the carburetor. Located in conduit **34A** is pressure regulating valve **38B**. The top of volatile fuel tank **33A** is connected through pressure relief valve **36A** by a second vapor conduit **37A** back to gasoline tank **30**.

Vapor chamber **37** connects through its bottom end closure to the inlet of volatile-depleted pump **38A**. The outlet of pump **38A** connects through volatile-depleted fuel conduit **39A** to gasoline tank **30**. Located in conduit **39A** is one-way check valve **30B**.

Drain conduit **31B** connects a drain outlet at the bottom of the carburetor fuel bowl such as drain **9** in FIG. **1** through valve **32B** to fuel conduit **31**.

Bimetal thermal switch **33B** responds to engine coolant temperature and is connected by actuating means to valves **34** and **35A**.

Located inside vaporizing chamber **37** is liquid level actuated switch **34B** which connects through the side wall of chamber **37** by actuating means **36B** to pump **38A**.

Located inside volatile fuel tank **33A** is liquid level actuated switch **35B** which is connected by actuating means **37B** to pump **38**.

In operation, starting with a cold engine, turning the ignition on causes drain valve **32B** to close. Thermal switch **33B** responding to the low engine temperature has valve **35A** in an open position and valve **34** in a closed position. Volatile fuel from volatile fuel tank **33A** flows through conduit **34A** and fills the fuel bowl of the carburetor. If required, an auxiliary fuel pump can be installed in conduit **34A**. This is not usually required because the volatile fuel is under slight pressure which is regulated by pressure regulator valve **38B** such that the volatile fuel at the carburetor can be controlled by a standard float actuated fuel bowl valve. Actuating the starter starts the engine which operates without choking using the volatile liquid fuel.

After 2–3 minutes of operation the liquid coolant temperature rises to a predetermined level at which experience has shown the particular engine can operate on normal gasoline without choking. Thermal switch **33B** senses this temperature and actuates valve **35A** to close and valve **34** to open. During continued operation normal gasoline is supplied to the carburetor from gasoline tank **30** through fuel conduit **31.**

Assuming the liquid level in volatile fuel tank **33A** has dropped below a predetermined level (this predetermined level should provide enough reserve volatile fuel to start and warm-up the engine), liquid level actuated switch **35B** closes which starts pump **38.** Pump **38** evacuates vaporizing chamber **37** pumping the residual vapor therein towards condenser **30A**. When the pressure in chamber **37** drops to a predetermined level, pressure regulating valve **36** opens and meters normal gasoline from gas tank **30** through conduit **35** into evacuated vaporizing chamber **37.** The predetermined pressure differential which causes pressure regulating valve **36** to open is such that the light ends of the normal gasoline will vaporize. A useful pressure differential is that which will cause up to about 10–50 per cent of the normal gasoline to vaporize. The normal gasoline thus admitted to the vaporizing chamber is partially vaporized due to the reduced pressure. The vapors formed are pumped by pump **38** towards condenser **30A** where they compress and liquefy releasing heat which is radiated by the finned-tube condenser **30A**. The condensate so formed is pumped through one-way check valve **32A** into volatile fuel tank **33A**. If non-condensables are included in the condensate and cause the pressure in volatile fuel tank **33A** to rise above about **5-75** psig, pressure relief valve **36A** opens and vents the non-condensables back to gas tank **30** until the pressure in volatile fuel tank **33A** drops to an acceptable level.

As fuel continues to be sucked into vaporizing chamber **37**, the volatile-depleted portion of the fuel collects at the bottom of chamber **37.** When the liquid level in chamber **37** reaches a predetermined level, liquid level actuated switch **34B** closes causing pump **38A** to operate which pumps the volatile-depleted fuel through volatile-depleted conduit **39A** and one-way check valve **30B** to gas tank **30.**

When the liquid level in volatile fuel tank **33A** rises to a satisfactory level, switch **35B** turns off pump **38.** As soon as the liquid level in vaporizing chamber **37** drops below the predetermined level, switch **34B** shuts off pump **38A**. At this stage the self-generation of volatile fuel is completed.

When the engine is stopped by turning off the ignition, drain valve **32B** opens and drains the fuel bowl. If the engine is restarted while still above operating temperature, valve **32B** will close; and since thermal switch **33B** is still sensing adequate operating temperature, valve **35A** will remain closed and valve **34** will be open. Hence, the carburetor will be supplied with normal gasoline. However, if the engine remains off long enough to lower the engine temperature below operating temperature, then valve **35A** will be open and valve **34** will be closed and the sequence will be as described above for starting a cold engine.

It is desirable to include in the vehicle an overrride system which cuts out the automatic fuel switch control by engine temperature. This is to handle the situation in which the engine is cold and thermal switch **33B** is signaling valve **35A** to open and deliver volatile fuel to the carburetor bowl during a period when the volatile fuel supply in tank **33A** has been depleted. In this event, the automatic system is cut-out and normal gasoline is delivered to the carburetor and the engine started in the conventional manner using a choke.

In another aspect of the invention it may be desirable to control the ratio between the pumping volumes of pumps **38** and **38A** so as to correspond to the ratio between the volumes of vapor and volatile-depleted fuel formed in vaporizing chamber **37.** In this manner, pumps **38** and **38A** operate concurrently. Similarly, by control of vacuum regulating valve **36** and the pumping rates of pumps **38** and **38A**, both the rate at which volatile fuel is separated from the whole gasoline and the distillation range of the volatile fuel can be regulated.

In a preferred embodiment of this invention an improved vaporizing system is employed which operates with a circulating gas stripping loop without the necessity for using a vacuum system.

The gas utilized as the stripping agent is not critical so long as it does not react with or substantially absorb in the normal gasoline, volatile fuel of volatile-depleted fuel. It should have good thermal properties and not condense under the operating conditions of the gas stripping loop. Any substantially inert gas may be employed in this invention. Preferably nitrogen, carbon dioxide, hydrogen, helium, argon, and methane are typical of the gases useful in this invention. It should be understood that practically any gas may be condensed under extreme pressure and very low temperature. However, for purposes of this invention the term non-condensable is understood to mean those gases which do not condense under the conditions of the system such as at ordinary temperatures and pressures of up to about 10 atmospheres. More preferred are those gases selected from nitrogen, methane, and carbon dioxide. Most preferably, nitrogen is used as the stripping gas.

The amount of stripping gas used is not critical and may be varied according to the amount of volatile fuel desired. Further, the design of the system, amount of heat added, if any, system pressure and temperature difference between the vapor-liquid separator and condenser will all have an effect on the amount of stripping gas required to obtain a desired amount of volatile fuel. The optimum amount of stripping gas used is best determined experimentally taking into account the amount and composition of volatile fuel required for a particular engine. Thus, a particular advantage of this feature of the invention is that it allows the volatile fuel to be tailor-made for the particular engine-type and can even allow for producing a volatile fuel peculiarly adapted to a specific engine. A useful amount of stripping gas ranges from about 0.1 to about 1 mole of stripping gas per mole of gasoline feed. Ratios below this amount can be used but only small amounts of volatile fuel are produced; while at ratios above this amount volatile cut is too deep resulting in carrying over some of the heavier components with penalties in cold starting and emissions.

The gas stripping loop can be operated either as a constant pressure system or as a constant temperature system. Under constant temperature, the inert stripping gas volatilizes a portion of the normal gasoline, the vapor (containing inert gas) and liquid residual fuel are separated, the vapor is then compressed to liquefy the light ends producing a liquid volatile fuel which is suitable for cold start and warm-up operation. The inert stripping gas is separated from the liquid volatile fuel and recycled to the volatilizing step. Typically, a wide range of conditions may be employed and the temperature is constantly maintained at a preselected value ranging from ambient to about 150° F. Without limiting the invention, the system pressures useful at the predetermined temperature may range from atmospheric to elevated pressure, e.g., about 100 psia. The stripping loop can be operated at pressures either greater or lower than this, but such operation suffers from the disadvantages of requiring more expensive vacuum apparatus or high pressure lines with resulting additional expense of equipment. The vapor must be compressed at a higher pressure than the stripping occurs; generally from about 50 to 100 psia higher to obtain efficient condensation.

In the constant pressure stripping system the volatile fuel generation system is maintained at the same pressure and the temperature is increased to aid vaporization of the light ends of gasoline, producing the volatile fuel. The constant pressure system can be operated under sub-atmospheric, atmospheric, or super-atmospheric pressures in the gas stripping loop. Preferably the system is under atmospheric or super-atmospheric pressure. Most preferably the system pressure ranges from about 20 to about 100 psia. At any given pressure the system should maintain at least a 50° F temperature differential between the vaporizing and condensing systems. Temperatures of from about 75° F to about 250° F may be used; however, the best temperature in both the first vapor-liquid separator (a convenient place to measure the vaporization temperature) and the condenser should be determined experimentally for each system depending on its own individual characteristics, the amount and composition of volatile fuel desired and the set pressure for the system. A typical temperature for 30 psia in the system is 175° F in the first vapor-liquid separator and 125° F in the condenser. Of course the incoming gasoline feed should be heated higher to allow for cooling on vaporization, for example, to about 215° F. These temperatures and pressures are merely illustrative and should not limit the invention which is operable over a wide variety of pressures and temperatures.

Since the constant pressure system does not require compression to cool the vapor and produce liquid volatile fuel, the system is simpler in operation. Therefore, the concept of this invention is more easily demonstrated by reference to the constant pressure volatile fuel generation system using a circulating gas stripping loop.

Referring to FIG. 4 the gas stripping loop is shown to contain a mixing nozzle **40** connected by a liquid conduit **41** to a pump **41A** which supplies gasoline from the normal gasoline tank **44.** The liquid conduit includes a heating section **41B** which is used to heat the normal gasoline. A vapor-liquid conduit **47A** brings the mixture from the mixing nozzle **40** to the vapor-liquid separator **42.** The vapor-liquid separator **42,** is, in turn, connected by vapor conduit **53** to condenser **45** for taking off the vapors. Discharge line **44A** connects the bottom of separator **42** to trap **44B** which removes the liquid from the gas stripping loop without removing the vapors in the loop. Discharge line **44C** connects to a storage vessel, or to the gas tank or to the fuel induction means. Vapor conduit **43** connects the top of separator **42** to condenser **45** which is connected at its other end to second vapor-liquid separator **46.** Liquid discharge line **48** connects the bottom of separator **46** through trap **48B** to the volatile fuel tank. Vapor conduit **47** connects the top of separator **46** through pump **47B** back to the mixing nozzle **40** thus completing the stripping loop. An inert gas storage cylinder **49** is connected to the vapor conduit **47** through a conduit **49A.** A pressure regulator valve **49B** in conduit **49A** delivers inert gas from the storage cylinder to maintain the desired pressure in the stripping loop.

In operation normal fuel is fed from the gasoline tank to pump **41A** which raises the pressure of the gasoline to the pressure of the stripping loop. Pump **41A** forces the gasoline through conduit **41** to heater **41B** where heat is added to bring the gasoline to the temperature of the stripping loop and to supply the heat of vaporization for a portion of the gasoline. It is sufficient if the heating means increases the temperature of the gasoline to at least about 25° F higher than that of the stripping gas. Conduit **41** leads the heated gasoline to mixing nozzle **40** where it is atomized and mixed with inert gas in conduit **47A.** Partial vaporization takes place immediately in conduit **47A** and the vapor-liquid mixture is conducted to vapor-liquid separator **42.** In vapor-liquid separator **42,** the residual fuel settles to the bottom, and is discharged through trap **44B** and line **44C** to either a storage tank, gasoline tank **44,** or directly to the carburetor. The circulating gas and vapor are taken from the vapor-liquid separator **42** through conduit **43** to condenser **45** where the gas and vapor is cooled and a portion of the vapor liquefies producing the volatile fuel. This is separated from the remaining gas in the second vapor-liquid separator **46** and discharged for subsequent use through trap **48B** and line **48C.** The circulating gas and a small amount of uncondensable vapor are impelled by pump **47B** through conduit **47** and returned to mixing nozzle **40** for further fuel vaporization. A small amount of inert gas is removed from the stripping loop, dissolved in the residual liquid and the volatile liquid. These losses are automatically replenished by regulator valve **49B** which delivers inert gas from storage cylinder **49.**

FIG. **5** shows the improved fuel volatilizing system employing a circulating gas stripping loop in the fuel system of an internal combustion engine and operates essentially in the same manner as described in FIG. **4.** The dual fuel delivery system shown in FIG. **5** operates as described for FIG. **3** above. The schematic shows gasoline tank **50** connected by liquid fuel conduit **51** to fuel inlet **52** of the carburetor. In fuel conduit **51** is fuel pump **53** and fuel selector valve **54.** A second liquid fuel conduit **55** connects gasoline tank **50** with pump **56** which connects through conduit **57,** heater **58** and check valve **59** to mixing nozzle **60.** Conduit **61** brings vapor and liquid from nozzle **60** to the vapor-liquid separator **62** which may be any commercially available impingement separator designed for application in this particular instance. Vapor-liquid separator **62** is connected to the inlet of finned-tube condenser **63** by vapor conduit **64** from the vapor outlet of vapor-liquid separator **62.** The outlet of condenser **63** is connected by volatile fuel stripping gas conduit **65** to a second vapor-liquid separator **66.** The liquid outlet of separator **66** is connected through trap **67** and one-way check valve **68A** to volatile fuel tank **68** by liquid volatile fuel conduit **67A.** The bottom of volatile fuel tank **68** is connected by liquid volatile fuel conduit **69** through pressure fuel regulating valve **76** and fuel selector valve **70** to the fuel inlet **52** of the carburetor. The vapor outlet of the second vapor-liquid separator **66** is connected by a second vapor conduit **71** to vapor pump **72.** Conduit **73** leads from pump **72** back to mixing nozzle **60,** thus completing the vapor stripping loop.

The top of volatile fuel tank **68** is connected through pressure relief valve **76A** by vapor conduit **74A** back to gasoline tank **50.**

The first separator **62** is connected to gasoline tank **50** by volatile-depleted fuel conduit **74** through trap **75.**

Drain conduit **51B** connects a drain outlet at the bottom of the carburetor fuel bowl such as drain **9** in FIG. **1** through drain valve **52B** with fuel conduit **51.**

Thermal switch **53B** responds to engine coolant temperature and is connected by actuating means to fuel selector valves **54** and **70.**

A cylinder of inert gas **77** is connected to inert gas conduit **71** through conduit **79.** The inert gas from cylinder **77** is automatically added to conduit **79** through regulator valve **78.**

Located inside the volatile fuel tank **68** is liquid-level actuated switch **74** which is connected by actuating means **75A** to pump **56** and by actuating means **75B** to pump **72.**

In operation, starting with a cold engine, turning the ignition on causes drain valve **52B** to close. Thermal switch **53B** responding to the low temperature in the engine coolant, or other temperature sensing location, has fuel selector valve **70** in an open position and fuel selector valve **54** in a closed position. Volatile fuel from volatile fuel tank **68** is forced by its internal pressure through pressure regulating valve **76,** through conduit **69** and fills the fuel bowl of the carburetor. Actuating the starter starts the engine which operates without choking using the volatile fuel.

After a short period of operation, usually 2–3 minutes, the liquid coolant temperature rises to a predetermined level at which experience has shown the particular engine can operate on normal gasoline without choking. Thermal switch **53B** senses this temperature and actuates valve **70** to close and valve **54** to open. During continued operation normal gasoline is delivered to the carburetor from gasoline tank **50** through fuel conduit **51.**

Assuming the liquid level in volatile fuel tank **68** has dropped below a predetermined level (which level should provide enough reserve volatile fuel to start and warm-up engine), liquid-level actuated switch **74** closes and starts pump **56** and gas pump **72.** Pump **56** forces normal gasoline through heat exchanger **58** where it is heated to a level which facilitates vaporization of a portion of the normal gasoline. Heat can be furnished by an electrical resistance coil operated by battery or the automobile electrical system, or by hot engine coolant or by hot exhaust gas. Any arrangement suitable for bringing the gasoline to a temperature sufficient to aid volatilization is suitable. A convenient temperature differential is about 25° F higher than the temperature of the stripping gas. The heated normal gasoline then flows through mixing nozzle **60** where it is atomized and intimately mixed with the inert gas in the stripping loop. The light ends are immediately vaporized. The vapor-liquid mixture then flows into the first vapor-liquid separator **62** where the liquid which is a volatile-depleted fuel settles to the bottom of the separator **62.** The vapor which is carried by the inert gas flows out the top through vapor conduit **64** toward condenser **63** where it is cooled and condensed forming the volatile fuel. The mixture of non-condensable inert stripping gas and liquid volatile fuel flows out of condenser **63** to the second vapor-liquid separator **66** through conduit **65.** The volatile fuel is separated from the inert circulating gas and is discharged through liquid trap **67,** check valve **68A** to volatile fuel tank **68.** The inert gas and any non-condensables flow through the vapor outlet of separator **66** into conduit **71** and are pumped by means of pump **72** through conduit **73** back to the mixing nozzle **60.** Any inert gas which escapes from the gas stripping loop is made up from a high pressure storage cylinder **77.** Pressure regulating valve **78** automatically adds inert gas through conduit **79** to maintain a constant pressure in the gas stripping loop.

As fuel continues to be vaporized in mixing nozzle **60,** the liquid separated in the first vapor-liquid separator **62** collects at the bottom of the separator. This volatile-depleted portion of the fuel is automatically drained from the separator with very little loss of inert gas by means of trap **75.** Conduit **74** leads this volatile-depleted fuel to conduit **51** through which it may flow to gasoline tank **50** or to normal gasoline fuel pump **53.**

When the liquid level in volatile fuel tank **68** reaches a satisfactory level, switch **74** shuts off pumps **56** and **72.** At this stage self-generation of the volatile fuel is completed.

On stopping the engine the fuel selector valves and thermal switch operate as described hereinabove for FIG. **3** to assure that the fuel bowl of the carburetor is drained and that the temperature sensing switch actuates the valves to allow the proper fuel to be supplied to the carburetor.

I claim:

1. In a spark ignited internal combustion engine, a process for producing a volatile fuel from a liquid hydrocarbon fuel of the gasoline boiling range comprising vaporizing a portion of said liquid hydrocarbon fuel of the gasoline boiling range in a pressurized gas stripping loop by contacting with a substantially inert stripping gas circulating under pressure, separating the vapor and said stripping gas from the residual fuel, condensing the vapor to produce a liquid hydrocarbon fuel of the lower gasoline boiling range for use during a selected period of engine operation, separating said liquid hydrocarbon fuel of the lower gasoline boiling range from said stripping gas and recycling said stripping gas to the contacting step.

2. A process of claim **1** wherein said stripping gas is nitrogen.

3. A process of claim **1** wherein said liquid hydrocarbon fuel of the gasoline boiling range is heated prior to said contacting.

4. A process of claim **1** wherein said stripping gas is characterized by being non-reactive with the hydrocarbon fuels and non-condensable under the conditions used in the process.

5. A process of claim **4** wherein said stripping gas is selected from the group consisting of nitrogen, argon, helium, carbon dioxide, hydrogen, and methane.

6. A process of claim **1** wherein said liquid hydrocarbon fuel of the gasoline boiling range is heated to aid vaporization and the gas stripping loop is maintained at the same pressure.

7. A process of claim **6** wherein the gas stripping loop pressure ranges from about 20 to about 100 psia.

8. In a liquid fuel system for a spark ignited internal combustion engine adapted to deliver liquid hydrocarbon fuel of the gasoline boiling range to the fuel induction means and to deliver liquid hydrocarbon fuel of the lower gasoline boiling range to said fuel induction means during selected periods of engine operation, the improvement comprising a pressurized circulating gas stripping loop including:

a. mixing means adapted to mix said liquid hydrocarbon fuel of gasoline boiling range with a substantially inert stripping gas whereby a portion of said liquid hydrocarbon fuel of the gasoline boiling range is vaporized and a vaporous mixture of hydrocarbon fuel of the lower gasoline boiling range and inert stripping gas is formed,

b. separating means to recover said vaporous mixture from the residual fuel,

c. means to condense liquid hydrocarbon fuel of the lower gasoline boiling range from said vaporous mixture,

d. means to separate said liquid hydrocarbon fuel of the lower gasoline boiling range from said stripping gas, and

e. means to feed said stripping gas to said mixing means.

9. The fuel system of claim **8** having pump means in said means to feed said stripping gas for circulating said stripping gas.

10. The fuel system of claim **9** having a liquid fuel conduit connecting the gasoline tank to said mixing means, heating means in said liquid fuel conduit

adapted to heat said liquid hydrocarbon fuel of the gasoline boiling range prior to said mixing whereby the vaporization of said liquid hydrocarbon fuel of the gasoline boiling range is facilitated.

11. The fuel system of claim **10** wherein said heating means increases the temperature of said liquid hydrocarbon fuel of the gasoline boiling range to at least about 25° F higher than that of said stripping gas.

12. The fuel system of claim **8** wherein said mixing means is a mixing nozzle designed to atomize said stripping gas with said liquid hydrocarbon fuel of the gasoline boiling range whereby a portion of said liquid hydrocarbon fuel of the gasoline boiling range is vaporized.

13. In a method of operating a spark ignited internal combustion engine adapted to reduce noxious exhaust emission, said method comprising delivering liquid hydrocarbon fuel of the lower gasoline boiling range to the fuel induction system of said engine during start and warm-up of said engine and delivering liquid hydrocarbon fuel of the normal gasoline boiling range to said fuel induction system after said engine attains normal operating temperature, the improvement comprising generating said liquid hydrocarbon fuel of the lower gasoline boiling range from the liquid hydrocarbon fuel of the normal gasoline boiling range by mixing with said liquid hydrocarbon fuel of the normal gasoline boiling range a pressurized circulating substantially inert stripping gas, whereby a portion of said liquid hydrocarbon fuel of the gasoline boiling range is vaporized, separating said gas containing the vapor from the residual fuel which is depleted in volatile components, condensing said vapor from said gas to produce a liquid hydrocarbon fuel of the lower gasoline boiling range, separating said liquid hydrocarbon fuel of the lower gasoline boiling range from said gas and recirculating said gas to said mixing step, said liquid hydrocarbon fuel of the lower gasoline goiling range being available for use during start and warm-up of said engine.

14. The method of claim **13** wherein said mixing is carried out by a mixing nozzle designed to atomize said gas with said liquid hydrocarbon fuel of the gasoline boiling range.

15. The method of claim **13** having a pump means to provide for recirculating said gas.

16. The method of claim **13** wherein said liquid hydrocarbon fuel of the gasoline boiling range is heated prior to contacting with said stripping gas to facilitate the vaporization.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,799,125 Dated March 26, 1974

Inventor(s) Donald O. Hutchinson

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

Col. 3, line 49, reads shows "tha", should read shows -- the --. Col. 4, line 40, reads "eydrocarbons", should read -- hydrocarbons --. Col. 12, line 12, reads "53", should read -- 43 --. Col. 16, line 39, reads "goiling", should read -- boiling --. First page, Col. 2, line 7, reads "James W. Pelton", should read -- James M. Pelton --.

Signed and sealed this 10th day of September 1974.

(SEAL)
Attest:

McCOY M. GIBSON, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents