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[54] FUEL SYSTEM FOR GASEOUS FUELED ENGINES

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

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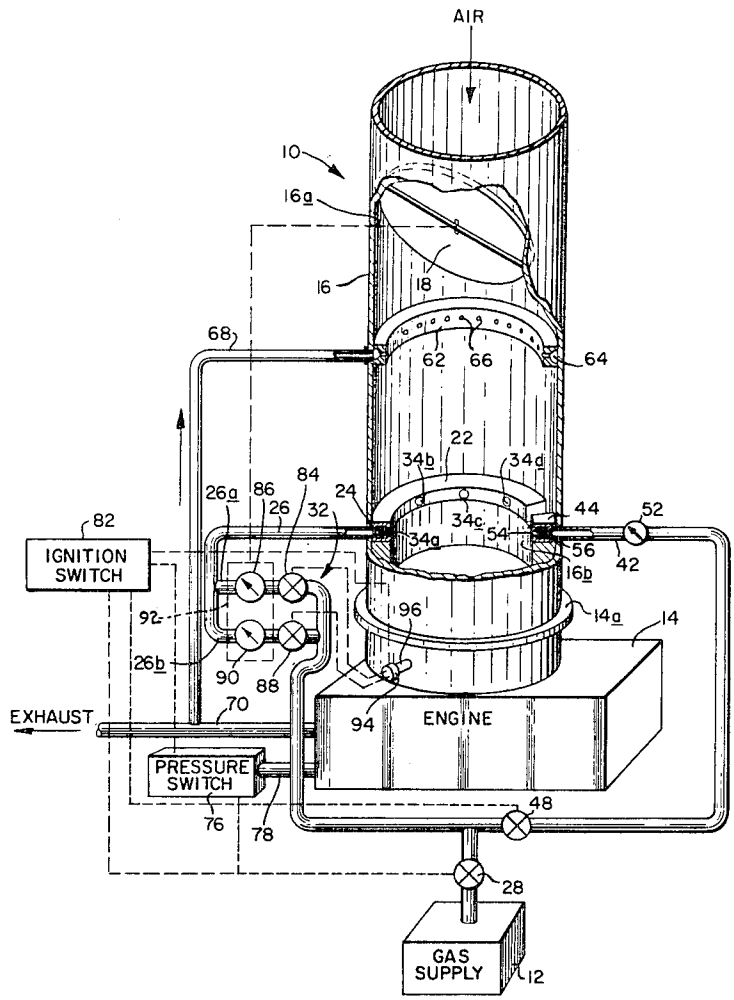
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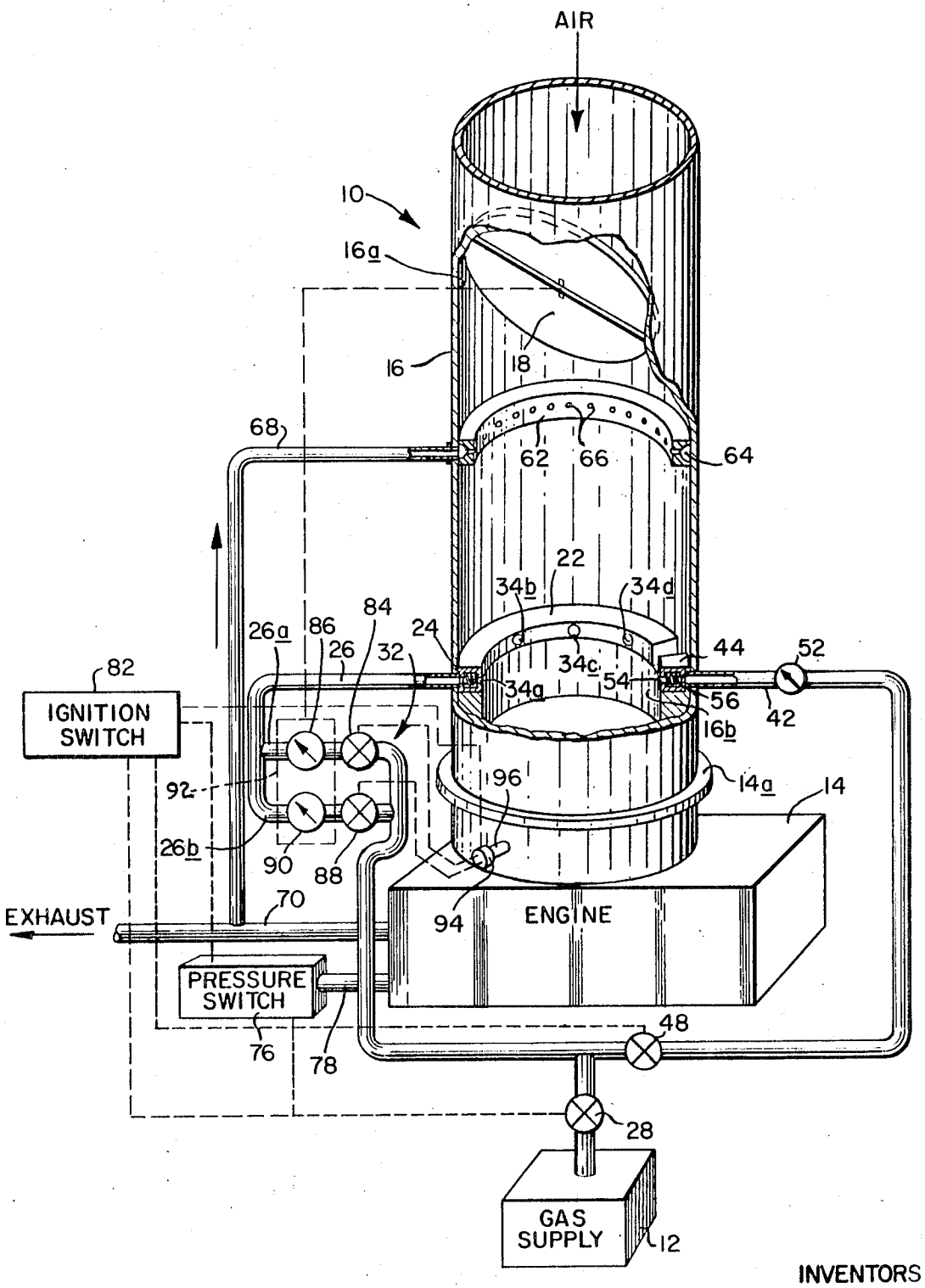
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[57] **ABSTRACT**

A gaseous fueled engine has a dual fuel feed system which provides a lean fuel-air mixture for starting the engine when it is cold and a richer mixture for starting or operating the engine after it is already warmed up.

7 Claims, 1 Drawing Figure





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FUEL SYSTEM FOR GASEOUS FUELED ENGINES

BACKGROUND OF THE INVENTION

This invention relates to a fuel system for a gaseous fueled engine and particularly an engine of the type consuming hydrogen. Hydrogen fueled engines are particularly desirable because the principal exhaust product of hydrogen is water vapor which does not pollute the atmosphere. A fuel system of this general type is disclosed in copending application Ser. No. 81,424, filed Oct. 16, 1970, entitled FUEL SYSTEM, which application is owned by the assignee of the present application.

The present invention relates more particularly to an improved fuel feed system of this general type which delivers a highly combustible fuel-air mixture to the engine when the engine is subjected to different starting and operation conditions.

While the fuel system described in the above-cited application operates satisfactorily in many situations, we have found that engine performance is quite dependent upon the temperature of the engine. In other words, a fuel-air mixture which starts or operates the engine efficiently after it is already warmed up is not the proper fuel-air mixture to start the engine when it is cold. Either the cold engine does not start at all or it takes an inordinate amount of cranking to start the engine, giving rise to an excessive drain on the engine battery. The same sort of problem exists with conventional gasoline engines. However, the techniques used to alleviate that problem in the case of gasoline engines do not work at all with hydrogen fueled engines. In fact, they only compound the problem.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a fuel feed system for use particularly with hydrogen fueled engines which enables the engine to start quickly under most prevailing operating conditions.

Another object of the invention is to provide a fuel feed system which enables a hydrogen fueled engine to operate more efficiently at different engine temperatures.

Still another object of the invention is to provide a fuel feed system of this type which is relatively easy to make and install.

A further object of the invention is to provide a fuel feed system of this type which is simple to operate and is easy to maintain.

Yet another object of the invention is to provide a gaseous fueled engine having a fuel feed system with one or more of the above characteristics.

Other objects will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the features of construction, combination of elements and arrangement of parts which will be exemplified in the construction hereinafter set forth and the scope of the invention will be indicated in the claims.

Briefly, we have discovered that a hydrogen fueled engine demands a lean fuel-air mixture in order to turn over and run readily when the engine is cold. Accordingly, our engine is provided with a dual fuel feed system with two branches connected in parallel between the gas supply and the engine carburetor. Each branch contains a valve and a pressure regulator, the latter being controlled by a single throttle linkage in conjunction with the usual butterfly valve in the carburetor air intake. A third fuel line from the gas supply to the carburetor delivers a preset amount of fuel for idling the engine.

One branch of the dual fuel feed system is open only during sustained engine operation or when starting an engine that is already warmed up. That is, its valve is open only when the engine temperature exceeds a determined value. The other branch of the system is open only when starting a cold engine; its valve is open only when the engine temperature is below that set value. The valves in the two branches are controlled by conventional switch means which respond to engine temperature. Each open branch of the fuel feed system delivers gas to the carburetor to supplement that delivered by the third, idling fuel line.

The pressure regulator in the branch of the fuel system supplying the engines needs during warm start or normal engine operation is variable over the entire range of gas pressures required to meet the engine's needs at all practical loads and speeds. Typically, this range extends from zero p.s.i. to 70 p.s.i. On the other hand, the pressure regulator in the cold start branch of the system is adjustable only over a relatively small portion of the former range. That is, it extends from zero to about 25 p.s.i. Thus, one regulator provides a relatively coarse fuel pressure adjustment over a relatively wide range when the engine is already warmed up. The other regulator functioning only when starting a cold engine provides relatively fine adjustment of fuel pressure over a much narrower range of pressures. When starting a cold engine, then, the throttle can be opened to deliver to the engine a much leaner, more highly combustible fuel-air mixture than is possible using prior fuel systems.

When the operator cranks the engine initially, the cold start branch of the system is open while the other branch is closed. Thus, when he opens the throttle, a relatively small amount of gas is mixed with the air entering the carburetor. This gas supplements the gas fed through the idling fuel line and mixes with the incoming air to provide a relatively lean, but very highly combustible, mixture in the carburetor which ignites readily even though the engine is cold. The operator can increase the speed of the engine somewhat by opening the throttle further.

After a relatively short time, the engine temperature increases to the point where the engine can run on a richer fuel-air mixture. At this point, the cold start branch of the fuel system closes and the other branch opens. Consequently, a greater proportion of fuel is delivered to the carburetor for mixing with the incoming air so that a richer fuel-air mixture is delivered to the engine for idling it under essentially no load after the engine is already warmed up. Now, by manipulating the throttle, the operator can vary the amount of fuel delivered to the engine over a wide range to meet the demands of the engine at various loads and speeds during normal driving.

With the present arrangement, then, a gaseous fueled internal combustion engine can be started more easily and run more efficiently and economically. Yet, the cost of the engine is not appreciably greater than prior engines of this type which lack these advantages.

BRIEF DESCRIPTION OF THE DRAWING

For a fuller understanding of the nature and objects of the present invention, reference should be had to the following detailed description taken in connection with the accompanying drawing in which the FIGURE is a diagrammatic view with parts cut away showing a fuel system for a gaseous fueled internal combustion engine embodying the principles of our invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Turning now to the drawing figure, a fuel system shown generally at **10** feeds hydrogen fuel from a cryogenic tank **12**, where the fuel is maintained in liquid form as a gas to an internal combustion engine **14**. The system includes a carburetor **16** having an air intake system **16*a*** into which air from the atmosphere is drawn. A throttle-controlled butterfly valve **18** is pivotally mounted in the intake section **16*a*** to regulate the flow of incoming air.

Fuel from tank **12** is injected as a gas into the mixing chamber **16*b*** of the carburetor below butterfly valve **18**. More particularly, a circular manifold **22** is positioned in the space below valve **18** within chamber **16*b***. Manifold **22** extends almost all the way around the wall of the chamber and has an internal passage **24** which runs almost the entire length of the

manifold. The fuel is conducted into the manifold passage **24** by way of a fuel line **26**. Line **26** includes a solenoid-operated valve **28** and a throttle-operated regulating section shown generally at **32** which will be described in more detail later. The regulating section is linked to butterfly valve **18** so that when the amount of fuel fed to manifold **22** is varied, the supply of air fed to the carburetor is increased or decreased proportionately.

Manifold **22** contains a number of radial ports **34**, four of which are shown and indicated as ports **34***a* to **34***d*. A ball check valve **36** located at each port is arranged so that fluid can flow from the passage **24** through the associated port and into the chamber **16***b*, but not in the opposite direction. Accordingly, the explosive fuel-air mixture in the carburetor cannot back up into the fuel lines and tank, thereby creating a safety hazard. As described in more detail in copending application Ser. No. 81,424 mentioned above, valves **36** are designed with progressively increasing cracking pressures so that if the operator opens the throttle, fuel enters the carburetor through a progressively increasing number of ports **34** to meet the demands of the engine. At the same time, sufficient air is drawn into intake section **16***a* due to the suction transmitted from engine manifold to maintain a highly combustible fuel-air mixture in the carburetor when the engine is operating normally.

The present system has a separate fuel feed section supplying the engine with the proper fuel-air mixture during idling. More particularly, fuel is fed from tank **12** via a separate fuel line **42** connected to fuel line **26** downstream from valve **28**. Fuel line **42** leads to a separate small manifold **44** in chamber **16***b*. Manifold **44** just fills the gap between the ends of manifold **22** so that both manifolds together form essentially a closed ring within chamber **16***b*. Line **42** has a solenoid actuated shutoff valve **48** for reasons to be discussed later, and a pressure regulator **52** which can be set to control the amount of fuel fed to the manifold during cranking and idling. Once regulator **52** has been properly set, it need not be adjusted thereafter.

Manifold **44** includes a port **54** and a check valve **56** in the port. Valve **56** allows fuel to flow outward through port **54**, but not in the opposite direction and it has a low cracking pressure, e.g., two p.s.i.

Fuel system **10** also includes another manifold **62** spaced above manifold **22** in carburetor section **16***a*. Manifold **62** is shaped like a ring, extending all around the inside wall of section **16***a*. This manifold is formed with an internal passage **64** extending almost all the way around it and it has a relatively large number of radial ports **66** communicating with this passage. In a typical embodiment of the invention, there are 30 such ports **66**.

A conduit **68** connects the engine exhaust manifold **70** to the manifold passage **64** so that at least part of the engine exhaust is fed to the manifold **62** for injection through ports **66** into intake section **16***a* above the point of injection of the fuel into the carburetor as described more specifically in the aforesaid copending application.

The present system also includes provision for shutting off the supply of gaseous fuel to the engine in the event that the engine does not start as it should. More particularly, a pressure switch **76** is connected to a line **78** extending to the engine and which reflects the oil pressure in engine **14**. Switch **76** is closed in response to the pressure buildup in line **78** due to increased oil pressure in the engine **14** when it is running. Switch **76** is connected electrically to the solenoid valve **28** and to the engine ignition switch **82**. Switch **82** is the usual type having ACCESSORY, OFF, IGNITION and START positions. The switch **82** is connected in parallel with switch **76** and valve **28** and the valve is normally closed.

To start the engine, the operator turns the switch **82** to START, whereupon the engine is cranked in the usual way and valve **28** opens allowing gas to flow through line **26** to throttle (regulator) **32**. As soon as the engine starts, the operator releases switch **82** which immediately returns to the IGNITION position. Now, however, with the engine turning over, there is sufficient pressure in line **78** to keep switch **76** closed so that the valve **28** remains open. Of course, if the engine does not start, when the operator releases switch **82**, valve **28** immediately closes so that there is no buildup of an explosive mixture in the various engine parts.

Valve **48** in the idling line is also controlled by switch **82**. It is open only when the switch is in its IGNITION position. Thus, once the engine starts and the operator releases switch **82**, valve **48** opens so that gas is also injected into the carburetor by way of manifold **44** to supplement that fed by line **26**.

If, for some reason, the engine should stall, the oil pressure in the engine soon drops so that switch **76** opens, thereby closing valve **28**. The gas supply remains shut off until the operator again cranks the engine by moving switch **82** to the START position.

We have discovered that gaseous fueled engines, particularly those consuming hydrogen, require a relatively lean fuel-air mixture when starting the engine initially or when idling it when the engine is cold. In other words, the desirable condition is exactly the reverse of the situation with conventional internal combustion engines which are cold-started on a relatively rich mixture. Once the present engine heats up to a reasonable degree, a richer fuel-air mixture is desirable to start and idle the engine. These two objectives are realized in the present case through the utilization of the regulating section **32**.

Within section **32**, fuel line **26** separates into two parallel branches **26***a* and **26***b*. Branch **26***a* includes an electrically operated fluid valve **84** connected in series with a pressure regulator **86**. Branch **26***b*, on the other hand, contains an electrically operated valve **88** and a pressure regulator **90**. Regulators **86** and **90** are adjusted by means of the same throttle control or pedal **92**. Pedal **92** is also linked mechanically with butterfly valve **18** so that when the operator adjusts the throttle control **92** to vary the amount of gas fed to the carburetor, the butterfly valve **18** is moved correspondingly to maintain the proper fuel-air mixture.

Valves **84** and **88** are connected electrically to a temperature responsive switch **94** which is mounted at a location to sense the temperature of the engine combustion chambers. In the present illustration, the switch **94** is mounted in the heat riser **96** which is found on most modern automobiles. The heat riser is essentially a conduit extending from the engine to the carburetor through which hot engine gases pass to actuate present-day automatic chokes. The present system has the switch **94** at essentially the same location in order to actuate the valves **84** and **88** at the proper times.

The temperature-responsive switch **94** is a double-throw switch which is also connected through the ignition switch **82** to the engine's electrical power supply. Switch **94** is active only when switch **28** is in the IGNITION or START position. When the engine temperature is below a selected value, e.g., 50° F., as would be the case when the engine is being cranked or idled from a cold start, switch **94** maintains valve **84** in the open position and valve **88** in the closed position so that all of the gas from supply **12** flows to the carburetor by way of branch **26***a*. Regulator **86** in branch **26***a* is adjustable from zero p.s.i. to about 25 p.s.i. By opening throttle **92**, the operator can obtain a very fine adjustment of the gas flow over this range. The hydrogen gas fed through branch **26***a* (along with that which may be supplied to the carburetor by way of the idling fuel line **42**) mixes with the incoming air to provide a relatively lean fuel-air mixture for the engine which ignites readily even though the engine is cold.

The engine starts and idles on this mixture until the engine heats sufficiently to actuate switch **94**. Whereupon, valve **84** closes and valve **88** opens so that fuel is supplied to the carburetor by way of branch **26***b*. Valve **88** preferably includes a dashpot arrangement which causes it to open relatively slowly so that there is no sudden power surge when the gas flow switches from branch **26***a* to branch **26***b*.

Regulator **90** in branch **26***b* is adjustable from zero p.s.i. to about 75 p.s.i. Relatively coarse adjustment over this wide range is achieved by manipulating throttle control **92**. The gas delivered by way of branch **26***b*, together with that fed through the idling branch **42**, upon mixing with the air entering the carburetor, provides a relatively rich mixture for powering the engine during normal driving conditions when the engine is already warmed up sufficiently to handle the richer mixture.

Thus, by delivering a relatively lean fuel-air mixture to the engine initially contrary to the prevailing practice, we are able to start the hydrogen-fueled engine even though it is cold initially. Furthermore, the system we use to accomplish this is relatively simple and does not increase the overall cost or complexity of the engine to any great extent. Furthermore, the present engine is safe to operate because steps are taken to insure that there is no inadvertent buildup of explosive gases in the engine parts.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above construction without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described.

We claim:

1. In a gaseous-fueled internal combustion engine including engine combustion chambers, a carburetor and a gas supply, the improvement comprising

A. at least two conduits connected in parallel between the supply and the carburetor, and

B. control means for directing the gas alternatively to one of said conduits or another of said conduits, said control means being responsive to engine temperature so that when the engine temperature is below a selected value, gas flows through the one conduit to the carburetor and when the engine temperature is above the selected value, the gas flows to the carburetor through the other conduit.

2. The engine defined in claim **1** and further including adjustable fluid pressure regulators in the one conduit and the other conduit, one of said regulators being adjustable over a relatively wide range, and the other regulator being adjustable over a narrower range.

3. The engine defined in claim **2**

A. wherein the carburetor includes a valve for adjusting the intake of air into the carburetor, and

B. further including means mechanically linking the control means and the valve in the carburetor so that when the gas flow to the carburetor is changed, the airflow thereto is changed correspondingly.

4. The engine defined in claim **2** wherein the adjustment of the pressure regulators is accomplished by a single throttle control element.

5. The engine defined in claim **1** wherein the control means comprise

A. a switch responsive to engine temperature, and

B. a separate solenoid-operated valve in each of said conduits connected to the switch so that the valves operate out of phase with each other.

6. The engine defined in claim **1** and further including

A. an electrically operated valve connected at the gas supply outlet, and

B. a pressure-responsive switch,

1. responsive to engine oil pressure, and

2. operatively associated with the check valve so as to close the valve when the oil pressure in the engine is below a determined value.

7. The engine defined in claim **1** and further including

A. a separate fuel line leading from the supply to the carburetor for feeding gas thereto when the engine is idling, and

B. means in the separate line for regulating the amount of gas fed to the carburetor.

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