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(54) **FUEL TANK SYSTEM FOR DIRECT ETHANOL INJECTION OCTANE BOOSTED GASOLINE ENGINE**

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(60) Provisional application No. 60/780,981, filed on Mar. 10, 2006.

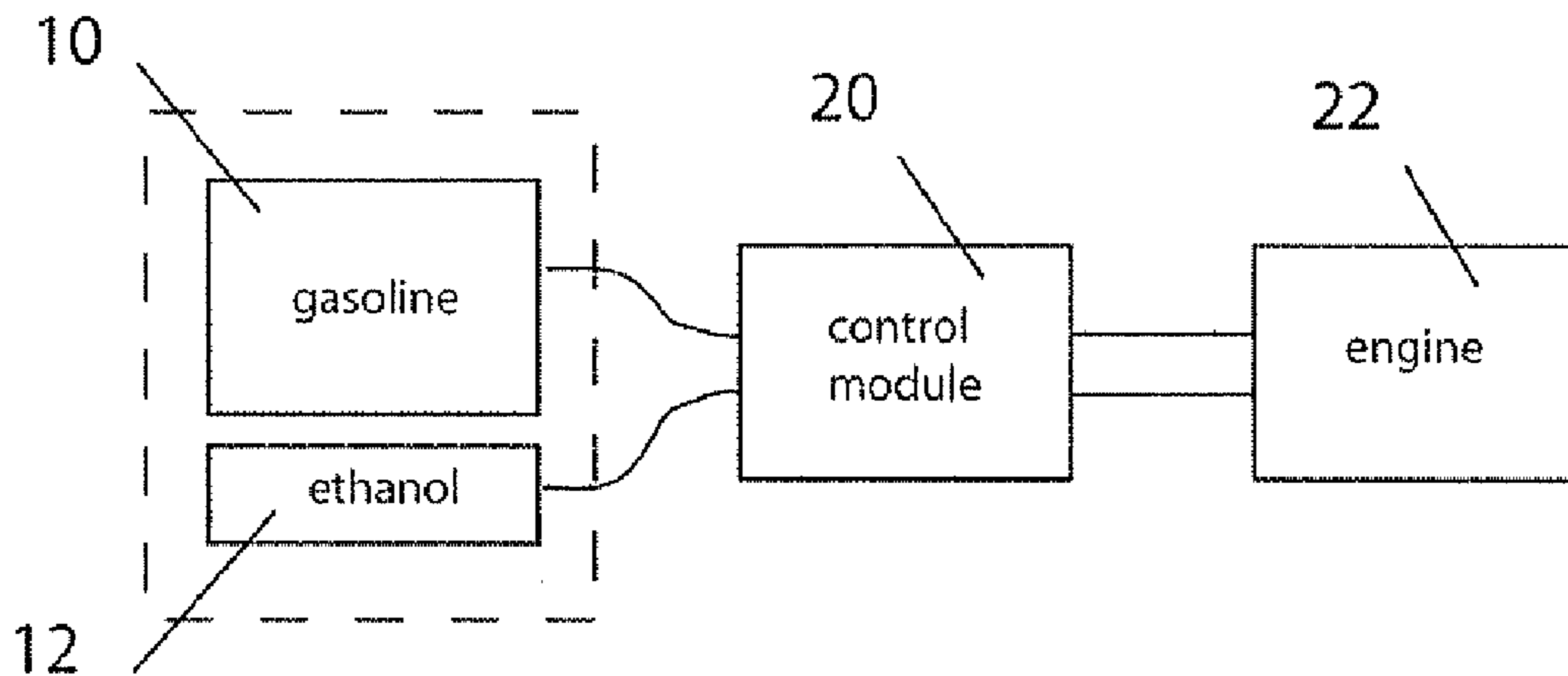
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(57) **ABSTRACT**

Fuel tank system for a direct ethanol injection octane boosted gasoline engine. The system includes a gasoline engine and a main fuel tank that contains a mix of gasoline and gasoline E85. A smaller secondary tank is provided to contain ethanol or E85. An injector directly injects in a separately controlled fashion ethanol or E85 into a cylinder of the engine to boost octane. A control module controls the relative amounts of gasoline and ethanol used and structure is provided for fueling the main and secondary fuel tanks.



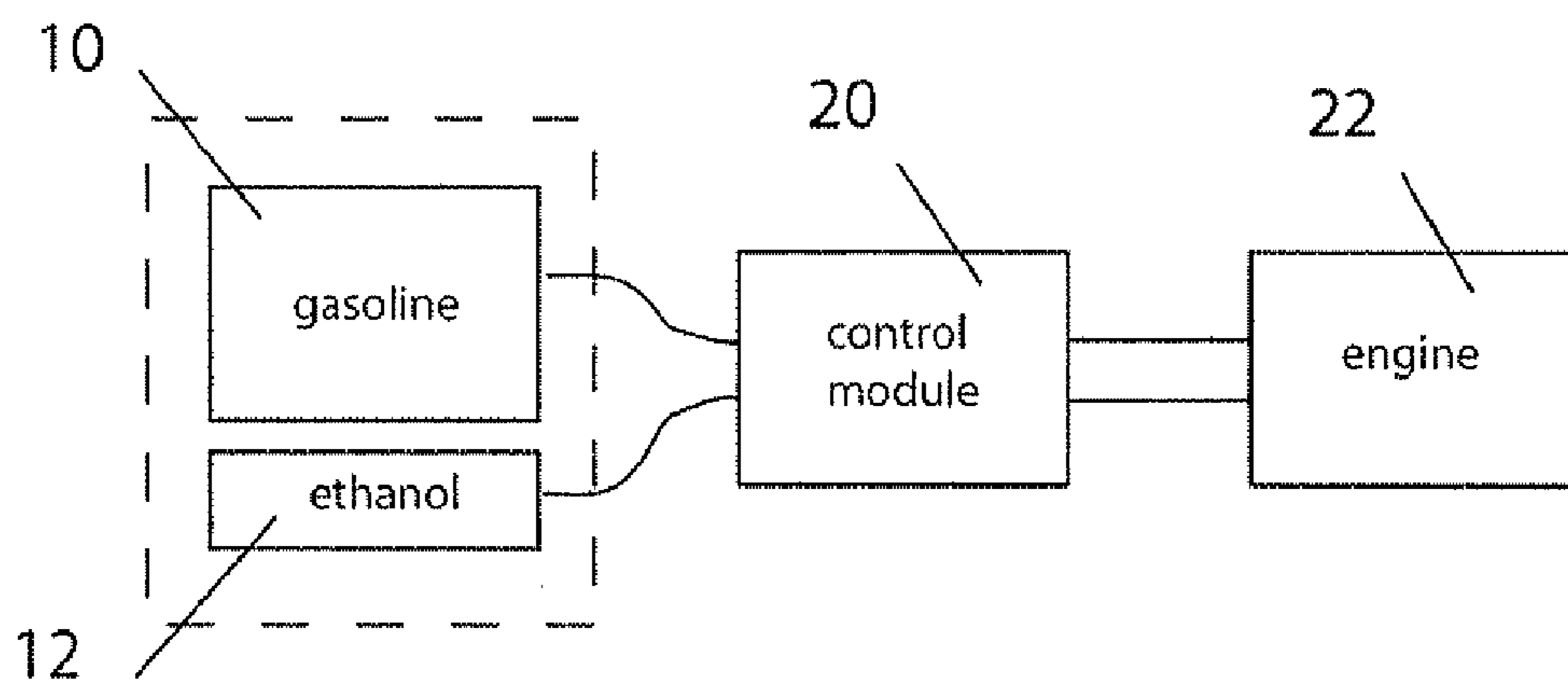


FIGURE 1

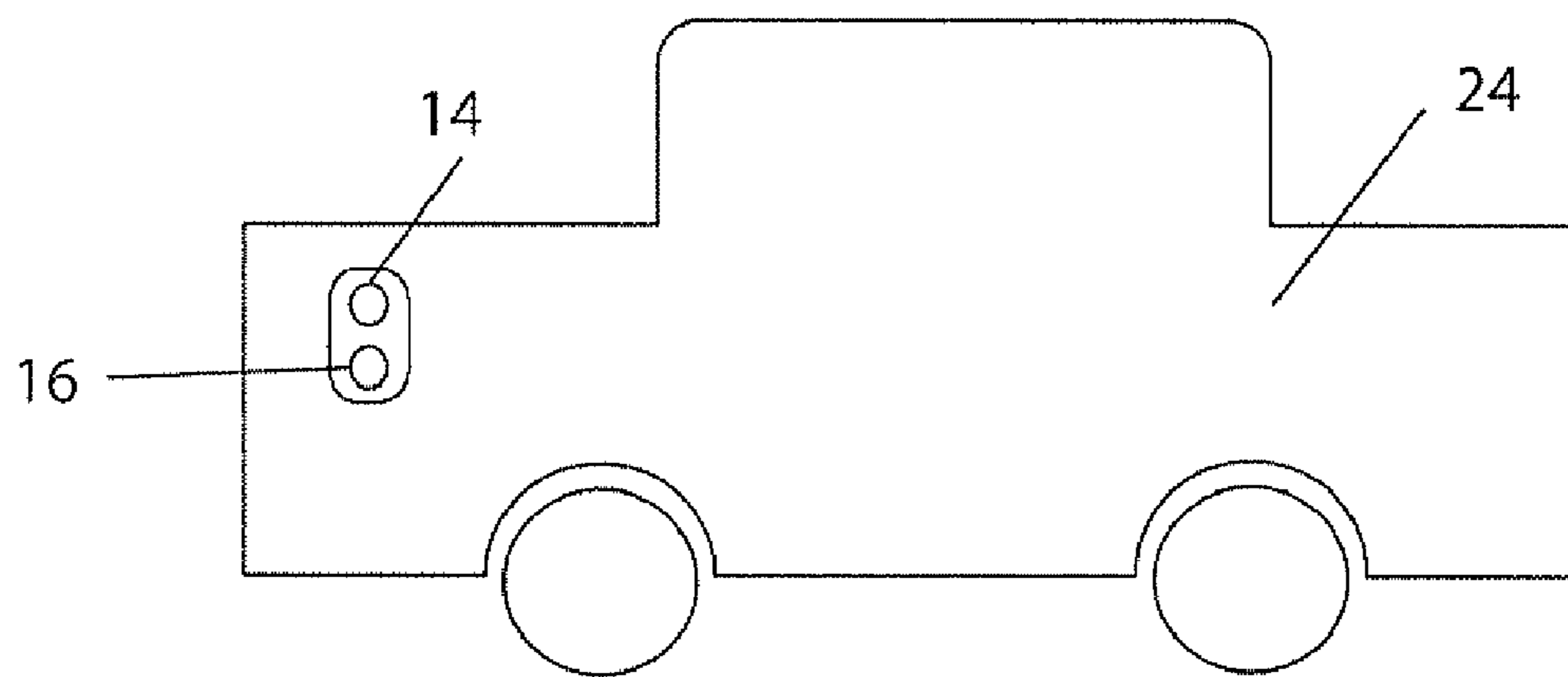


FIGURE 2

**FUEL TANK SYSTEM FOR DIRECT  
ETHANOL INJECTION OCTANE BOOSTED  
GASOLINE ENGINE**

**[0001]** This application claims priority of U.S. patent application Ser. No. 11/684,100, filed Mar. 9, 2007, which claims priority of U.S. Provisional Application Ser. No. 60/780,981, filed Mar. 10, 2006, the contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

**[0002]** This invention relates to a fuel tank system for a direct ethanol injection octane boosted gasoline engine.

**[0003]** As described in U.S. patent application Ser. No. 10/991,774 filed on Nov. 18, 2004 and application Ser. No. 11/100,026 filed Apr. 6, 2005, on-demand octane boost using direct ethanol injection can be used to enable high fuel economy in two types of vehicle operation. The contents of these applications are incorporated herein by reference. In the first, the vehicle is essentially powered by gasoline (with a minimal amount of ethanol used for on-demand octane boost). In another mode of operation when the cost and availability of ethanol make its use attractive, the vehicle is powered by a flexible fuel mix of E85 and gasoline. In this case, the E85 can constitute up to 100% of the fuel. In contrast to the use of ethanol as a fuel that is blended with gasoline, the driver has the freedom to determine when and how much ethanol to use. As will be described below, the amount of ethanol or E85 required to be stored in a separate tank for on-demand octane boost is on the order of only 4 to 20 gallons per year when a vehicle is essentially powered by gasoline. The requirement is less when the vehicle is powered by a flexible fuel mixture of ethanol or E85 and gasoline. The ethanol can be added using either 1.0 to 2.5 gallon containers or by the use of a pump at the growing number of E85 fueling stations in the United States. This small amount of ethanol could be provided for 50 million vehicles using less than 1 billion gallons of ethanol per year which is about 25% of the present U.S. ethanol production. Thus, the required extension of the ethanol transportation fuel infrastructure is very modest. Moreover, with the substantial increase in E85 infrastructure as presently planned by the 2005 Energy Act, additional ethanol can be used as a substitute fuel in addition to its use as an on-demand octane boost agent.

**[0004]** An object of the present invention is to minimize the inconvenience and cost of using a separate tank for the on-demand octane boost agent. Another object is a fuel management system designed so as to reduce the additional cost of flexible fuel operation.

SUMMARY OF THE INVENTION

**[0005]** The fuel tank system according to the invention for a direct ethanol injection octane boosted gasoline engine includes a gasoline engine and a main fuel tank for gasoline or E85. A smaller, secondary tank (octane boost tank) is provided to store ethanol or E85. An injector is provided for direct, separately controlled injection of ethanol or E85 into a cylinder of the engine to boost octane. A control module controls the relative amounts of gasoline and ethanol used and means for fueling the main and secondary fuel tanks is provided. In one embodiment, the means for fueling includes a single spigot with dual lines. In another embodiment, a first

fuel inlet fitting is provided that accepts a nozzle that dispenses gasoline or E85 and a second fuel inlet fitting is provided that accepts a nozzle that dispenses ethanol or E85. In yet another embodiment, the smaller secondary tank is fueled from a container or a pump. Suitable containers have volumes of 1.0 to 2.5 gallons. The system can further include a valve allowing both tanks to be filled from a single inlet fitting.

**[0006]** In yet another embodiment, the control module reduces the amount of ethanol or E85 from the secondary tank injected into the engine when the main tank contains E85. In another embodiment, the means for refueling refuels the main and secondary tanks simultaneously from a single fuel spigot having a nozzle design allowing gasoline into the main tank and ethanol into the secondary tank. It is also preferred that the capacities of the main and secondary tanks can be reconfigured. Such a reconfiguring may be on the basis of a previous driving pattern with an operator override. It is preferred that the engine be operated at a substantially stoichiometric air/fuel ratio so that 3 way catalytic converters can be used. In yet another embodiment, engine pressure boost, torque or horsepower is decreased to reduce consumption of ethanol.

BRIEF DESCRIPTION OF THE DRAWINGS

**[0007]** FIG. 1 is a block diagram illustrating an embodiment of the invention.

**[0008]** FIG. 2 is a schematic illustration of an embodiment of the fueling system disclosed herein.

DESCRIPTION OF THE PREFERRED  
EMBODIMENT

**[0009]** The fuel tank system disclosed herein uses a small separate fuel tank as a source of ethanol or E85 while the primary tank contains gasoline, E85, ethanol or a combination of these fuels. FIGS. 1 and 2 illustrate the fueling arrangement for a primary gasoline tank **10** and a secondary ethanol tank **12**. The small separate ethanol tank **12** is referred to as the secondary tank or octane boost tank. As shown in FIG. 2 there is one fuel inlet fitting **14** for E85 or ethanol and another fitting **16** for gasoline. The E85 fuel inlet fitting **14** is compatible with the pump nozzle that is currently used at E85 fueling stations. As shown in FIG. 1 the two tanks **10** and **12** could be integrated together into one unit **18**. Delivery of gasoline and ethanol from the integrated unit **18** is under the control of a control module **20** for delivery to an engine **22** that powers a vehicle **24**.

**[0010]** The octane boost tank **12** can be fueled from 1.0 or 2.5 gallon containers or by use of a pump. The refilling by containers can be carried out either by the driver or by a mechanic at the time of an oil change as part of routine servicing since the interval for ethanol refill could be on the order of three months or more.

**[0011]** The E85 fuel inlet fitting **14** can also accommodate E85 or ethanol that is added by containers in combination with a pour spout that could be screwed on to the container. Such a pour spout would be similar to the pour spout that is attached to present 2.5 gallon containers.

**[0012]** The octane boost tank **12** is sized so that the refill interval can generally be as long as three or more months under normal driving conditions. For example, a total fuel tank with a capacity of 22 gallons might have a capacity of 6 gallons for the octane boost tank **12** and 16 gallons for the gasoline tank **10**. Because of the increased fuel efficiency from the on-demand direct injection octane boost, this 16

gallon gasoline tank configuration will not lead to any decrease in range relative to a conventional 20 gallon gasoline tank.

[0013] Based upon the computational model described in the above identified pending applications, the required amount of ethanol or E85 to provide the on-demand octane boost for a 20% to 30% improvement in fuel economy is between 1 and 5 gallons for every 100 gallons of gasoline. The on-demand octane boost allows an increase in manifold pressure by a factor of 1.8 or more.

[0014] By way of illustration, assuming an annual gasoline consumption rate of 400 gallons a year (12,000 miles per year at 25 miles per gallon), the ethanol or E85 consumption rate is between 4 and 20 gallons a year, corresponding to 0.3 to 1.7 gallons per month. A representative consumption rate could thus be 1 gallon per month under normal driving conditions. Therefore, the use of a 6 gallon tank would allow for an ethanol or E85 refill interval of three months or more. This is approximately the same time interval as that for an oil change.

[0015] With E85 or ethanol comprising part, or even all of the fuel in the primary fuel tank **10**, the consumption of E85 or ethanol from the on-demand octane boost fuel tank **12** to prevent knock would be reduced. Hence the rate of use of E85 or ethanol from the on-demand octane boost tank **12** could be accordingly reduced and the refill interval for this tank can thus be extended.

[0016] The amount of E85 or ethanol drawn from the secondary fuel tank **12** can also be reduced by the control module **20** that may be activated by a driver. In this case, turbocharging, torque and/or horsepower capability would be decreased in order to reduce the demand for E85 or ethanol needed to insure knock free operation. This "octane boost economy" mode can also increase the refuel time interval and/or reduce the amount of E85 or ethanol that would be needed to be added at any time to the octane boost tank **12** at the expense of decreased power.

[0017] The control module **20** also controls, in one embodiment, the air/fuel mixture to provide substantially stoichiometric operation both during the time that the on-demand direct injection octane boost is used and when flexible fuel operation with ethanol or E85 in the primary tank **10** is employed. Stoichiometric operation makes it possible to use a three way catalytic converter which is highly effective in reducing emissions of pollutants in the engine **22** exhaust. Those skilled in the art will recognize that fuel injectors used for direct E85 or ethanol injection from the smaller tank **12** can also be used for injection of gasoline or E85 from the primary tank **10**.

[0018] If the price and availability of E85 are such as to motivate greater use in a flexible fuel mode, the octane boost tank **12** and the primary fuel tank **10** can be simultaneously fueled. In this way the time interval for separate refueling of the octane boost tank **12** is additionally lengthened. This mode can be accomplished by opening a valve (not shown) which allows E85 to flow into the main tank **10** in addition to the octane boost tank **12**. The valve can be controlled by a switch activated by the driver.

[0019] Another option for providing convenient pump refueling is to use a single spigot. In order to make it transparent to the driver, a single spigot with dual lines to the refueling station could be used to fill simultaneously both the main fuel tank **10** and the octane boost tank **12**. Such a system is similar to that proposed for diesel/SCR operation, but using gasoline/ethanol instead.

[0020] It is preferred to use a single spigot that refuels both the main fuel tank **10** and the on-demand octane boosting tank **12** in which the vehicle **24** determines how much of each fuel is needed, and the refueling station adjusts the rate and amount of fuel that is introduced into the vehicle. In this case, the vehicle **24** automatically determines how much fuel and ethanol octane enhancement is available, and how much is needed, assuming a pattern of driving that could include an onboard expert system that analyzes previous driving patterns.

[0021] The system disclosed herein can be arranged so that the onboard fuel management system reconfigures the fuel tank, adjusting the size of the respective tanks in order to provide the appropriate ratio of antiknock fuel to main fuel, with the refueling system just filling both tanks to capacity. This refueling can be achieved either with a single spigot with dual fuel dispensers, separated feeds, or a single feed with a valve to switch tank being refueled. This mode would be particularly useful for those engine designs and/or driving patterns that require substantial amounts of octane boosting agent.

[0022] The most transparent adjustment of the tank configuration (ratio of the capacities of the main fuel tank **10** and the on-demand octane boost tank **12**) occurs if the operation is done automatically by the fuel management control module **20**. However, the system can be most flexible if the operator can adjust the ratio, overriding the instructions from the control module **20** in order to best match future driving patterns (for example, before starting on a long trip with a highway driving pattern, or, conversely, after a long drive and readjusting to a city driving pattern).

[0023] Those skilled in the art will recognize that the above discussion applies to methanol and M85 as well as ethanol and ethanol blends such as E85.

[0024] It is recognized that modifications and variations will occur to those of ordinary skill in the art and it is intended that all such modifications and variations be included within the scope of the appended claims.

What is claimed is:

1. Fuel tank system for a direct ethanol injection octane boosted gasoline engine comprising:
  - a gasoline engine;
  - a main fuel tank that contains a mix of gasoline and E85;
  - a smaller secondary tank of E85;
  - an injector for separately controlled, direct injection of E85 from the secondary tank into a cylinder of the engine to boost octane;
  - a control module to control the relative amounts of gasoline and ethanol used; and
  - means for fueling the main and secondary fuel tanks.
2. The system of claim 1 wherein the means for fueling includes a single spigot with dual lines.
3. The system of claim 1 further including a first fuel inlet fitting accepting a nozzle that dispenses gasoline or E85, and a second fuel inlet fitting accepting a nozzle that dispenses E85.
4. The system of claim 1 wherein the smaller secondary tank is fueled by a container.
5. The system of claim 1 where in the smaller secondary tank is fueled by a pump.
6. The system of claim 4 wherein the container has a capacity of 1.0 to 2.5 gallons.
7. The system of claim 1 further including a valve allowing both tanks to be filled through use of a single inlet fitting.

**8.** The system of claim **1** wherein the control module reduces the amount of E85 injected into the engine when the main tank contains E85 or gasoline/E85 mixtures.

**9.** The system of claim **1** wherein the means of fueling refuels the main and secondary tanks simultaneously from a single dual fuel spigot having a nozzle design allowing gasoline into the main tank and ethanol into the secondary tank.

**10.** The system of claim **1** wherein the capacities of the main and secondary tanks can be reconfigured.

**11.** The system of claim **10** wherein the control module controls the reconfiguration on the basis of a previous driving pattern.

**12.** The system of claim **11** further including operator override of the control module to meet expected driving patterns.

**13.** The system of claim **1** wherein the engine is operated at a substantially stoichiometric air/fuel ratio.

**14.** The system of claim **1** wherein the direct injector also injects gasoline or E85 from the main tank.

**15.** The system of claim **1** wherein engine boost pressure, torque or horsepower is decreased to reduce consumption of E85.

**16.** Fuel tank system for a direct ethanol injection octane boosted gasoline engine comprising:

a gasoline engine;

a main fuel tank that contains a mix of gasoline and E85;

a smaller secondary tank of E85 an injector for direct, separately controlled, injection of E85 from the secondary tank into a cylinder of the engine to boost octane;

a control module to control the relative amounts of gasoline and ethanol used; and

means for fueling the main and secondary fuel tanks; and

wherein the injector for direct injection of E85 from the

secondary tank is also used to inject gasoline or E85

from the first tank and wherein the fuel/air mixture is

substantially stoichiometric.

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