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Coffee

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[54] **METHOD AND APPARATUS FOR STORING GASES AND FUELING INTERNAL COMBUSTION ENGINES**

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[58] **Field of Search**.....55/74, 75, 387, 389; 220/85 VS, 85 VR; 123/136

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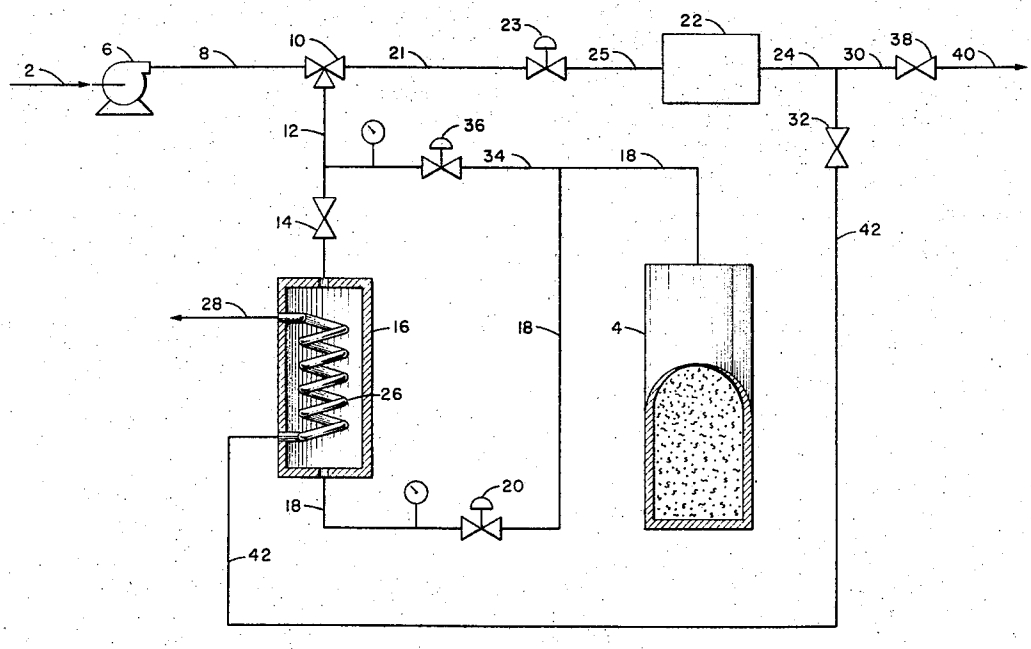
Primary Examiner—Charles N. Hart

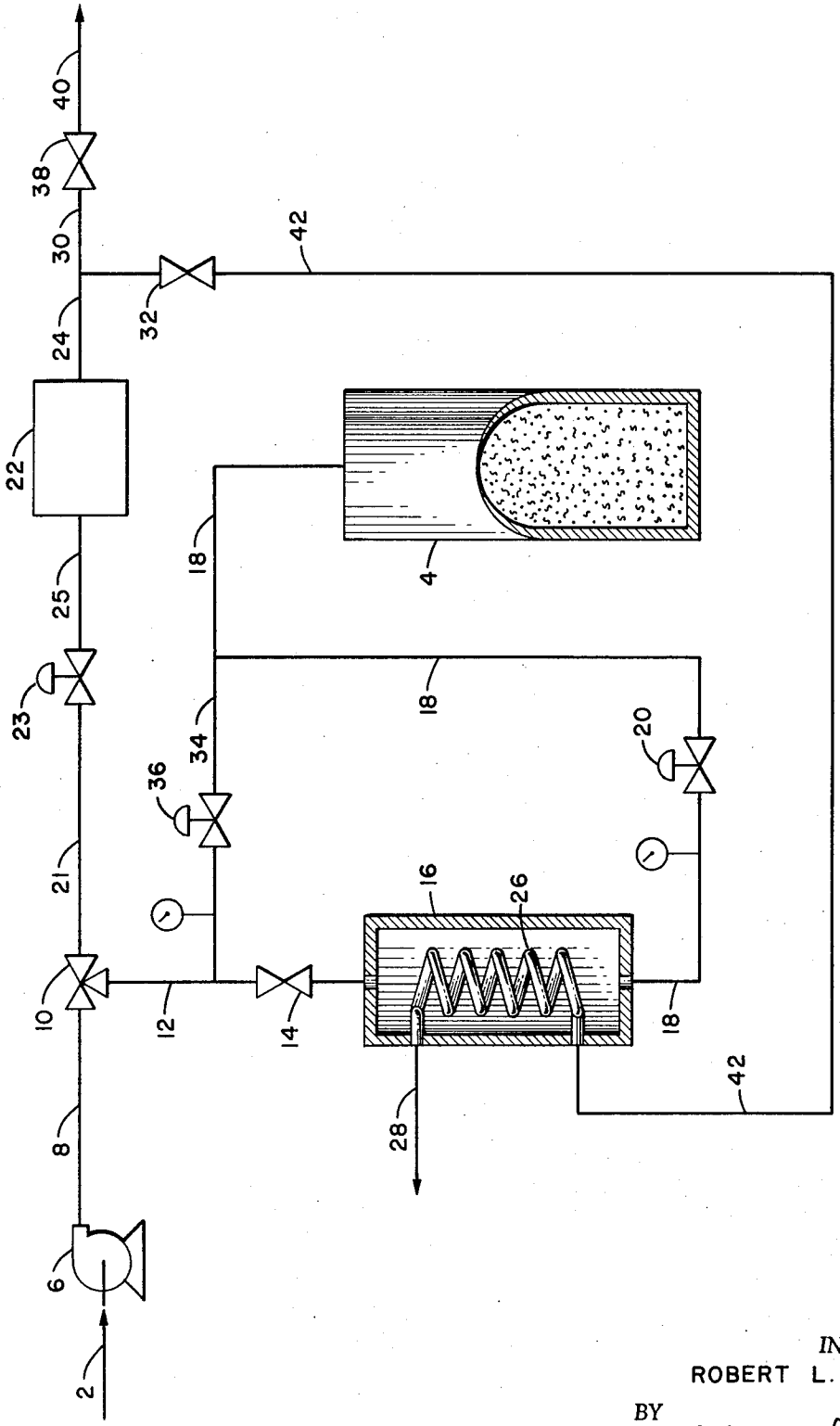
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[57] **ABSTRACT**

An impure stream of fuel gas is purified by passing the stream through a sorbent body which absorbs the impurities. The purified stream is then absorbed under pressure in a tank containing a suitable absorbent. The fuel gas is subsequently released to an internal combustion machine or other consumer of fuel gas for burning. The heated exhaust gases are flowed through the first purifying sorbent body to heat it and vaporize the unwanted impurities thus regenerating the sorbent body for a new cycle.

10 Claims, 1 Drawing Figure





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METHOD AND APPARATUS FOR STORING GASES AND FUELING INTERNAL COMBUSTION ENGINES

FIELD OF THE INVENTION

This invention relates to the storage of gas in containers. More specifically, this invention relates to the storage of gas in pressure tanks which are used to supply gas fuel for a number of uses.

DESCRIPTION OF THE PRIOR ART

Internal combustion engines have in the past used hydrocarbon gases such as methane and ethane as fuel. The use of such engines is however ordinarily confined to stationary locations so that the engines can be connected directly to the gas source. The use of hydrocarbon gases to fuel mobile engines has required that the gas be compressed to high pressures in high pressure cylinders and the cylinders mounted on the mobile engine. The storage of appreciable quantities of gas in such cylinders has required extremely high pressures to make the operation commercially feasible. The use of high pressures in turn creates problems such as risks of explosion and resulting injury to the operator of the engine, particularly if the vehicle overturns or collides with some object. Stored hydrocarbon gases are also useful as a source of heating and of illumination and for numerous other uses obvious to those skilled in the art.

OBJECTS OF THE INVENTION

It is an object of the present invention to provide an improved method and apparatus for powering a mobile internal combustion engine using for fuel hydrocarbon gases stored under pressure less than those now necessary for storage. Another object of this invention is to provide a method and apparatus whereby a pressure tank may be connected both to the internal combustion engine and to a gas source and charged with fuel gas when the associated internal combustion engine is not operating. Another object of the invention is to provide a method of storing hydrocarbon gases such as methane at a pressure substantially less than those now required to store methane in gas cylinders. Another object of this invention is to provide an improved method and apparatus for storage of hydrocarbon gases as a fuel for heating, illumination and other uses.

SUMMARY OF THE INVENTION

Briefly stated, this invention comprises storing a feed gas for internal combustion engines within a pressure tank by adsorbing the fuel gas on an adsorbent contained within the tank. In one particular embodiment the invention further comprises fueling an internal combustion engine by first adsorbing the fuel gas under pressure within a pressure tank containing adsorbent and then releasing the gas to the fuel intake of an internal combustion engine.

BRIEF DESCRIPTION OF DRAWING

The accompanying drawing schematically describes one embodiment of my invention in which the pressure storage tank is connected both with the fuel gas source and an internal combustion engine.

DESCRIPTION OF PREFERRED EMBODIMENTS

One embodiment of the apparatus of my invention is depicted schematically in the accompanying drawing. Conduit **2** conducts the raw fuel gas, which is to be stored by adsorption in pressure storage tank **4**, to compressor **6**. Conduit **8** connects three-way valve **10** with compressor **6**. Conduit **12** interrupted by valve **14** extends from three-way valve **10** to adsorber column **16**. Adsorber column **16** is filled with an adsorbent which has an affinity for those components of the fuel gas which it is desired not to compress within the storage tank. Some of the adsorbents which can be used include silica gel, molecular sieve and activated carbon, Conduit **18** interrupted by pressure regulated valve **20** connects the other end of adsorber **16** with pressure storage tank **4**. Storage tank **4** is filled with a porous adsorbent capable of adsorbing the purified gas flowing in conduit **18**. Conduit **21** connects three-way valve **10** with internal combustion engine **22**. Conduit **24** interrupted by valve **32** connects the exhaust of internal combustion engine **22** with a length of coiled heat exchange tubing **26** which in turn connects with conduit **28**. Alternately, conduit **24** connects with conduit **30** through valve **38** into conduit **40**. Bypass conduit **34** with pressure regulated valve **36** is provided between conduit **18** and conduit **12** so that adsorption column **16** may be bypassed if so desired.

In practicing the method of this invention the source of gas to be compressed by adsorption within the storage tank need not be a completely pure gas. For example, it need not be a pure stream of methane but may contain traces of unwanted components such as ethane and heavier hydrocarbons. These are removed by flowing the gas through sorption column **16** containing a sorbent which will remove the undesired components. For example, to remove traces of ethane from a gas source the sorbent used can be molecular sieve, silica gel or activated carbon. Other sorbents which might be used for other impurities include a combination of molecular sieve, silica gel, activated carbon and the like.

In the apparatus diagramed in the accompanying drawing three-way valve **10** is used to divert the gas supply into the sorption column **16**. Subsequently, the same valve is used to divert a fuel gas released from its storage container into the internal combustion engine. Other valving arrangements can be substituted.

The fuel gas, after being passed through the sorption column, is flowed directly into the storage tank where it is adsorbed on the sorbent contained therein. As gas is adsorbed on the adsorbent therein, additional gas flows in and similarly is adsorbed. When as much gas as possible has been adsorbed (or less if desired) in the container, it is closed by closing valve **20**. When it is desired to combust the fuel gas in engine **22**, gas is released from container **4** through conduit **18** and through pressure regulated valve **20**. The fuel gas then flows through column **16** and through valve **14** into conduit **12** and valve **10** which has been changed to divert flow from conduit **12** into conduit **21**. From conduit **21** the gas flows through pressure regulating valve **23** and conduit **25** into engine **22** where it is consumed.

While gas is being released from container **4** it is desirable to regenerate or desorb the sorbent material in column **16** by heating it. This is accomplished by

flowing the hot exhaust gases through conduit **24**, through valve **32** and heat exchanger tube **26**. Heat is conducted from heat exchanger tube **26** into the sorbent bed. The adsorbed material therein is vaporized and vented through valve **14** and conduit **12** into the internal combustion engine as part of the fuel. The effluent exhaust gas from internal combustion engine **22** is released by way of conduit **28** connecting with heating coil **26**.

When the sorbent column **16** has been fully desorbed, valve **32** is closed and the effluent exhaust passes through conduit **30**, through valve **38** into conduit **40** and is released. Column **16** is then cooled by the flow of fuel gas from the storage tank **4**. When the adsorber column **16** is cool, gas flowing from storage tank **4** may be continued through it or rerouted through conduits **18** and **34**, valve **36**, conduit **12**, valve **10** and conduit **21** to said engine as desired. When the supply of gas from the storage tank is exhausted the system is then ready for recharging of the storage tank.

The sorbent column may optionally be affixed to the gas supply and regenerated by similar means when it is not desired to have said column attached to the vehicle etc. containing the internal combustion engine.

EXAMPLES

A gas stream having the following composition (mole percent) is available as fuel to be compressed by adsorption:

Methane 94.0 percent
Ethane 5.0 percent
Propane and heavier 1.0 percent

The gas stream initially at a pressure of 1,000 psia and 80° F is flowed into a sorbent column for removal of ethane and heavier hydrocarbons. The sorbent in the adsorption column is activated carbon. The column has an internal volume of 1.1 ft^3 filled with finely divided sorbent. Gas enters the column at a pressure of 1,000 psia and a temperature of 80° F. While flowing through the sorbent column ethane and heavier components are adsorbed. The residual pure methane flows into a storage tank having an internal volumn of 3.57 ft^3 filled with finely divided adsorbent. Pressure in the storage tank is 1,000 psia. About 1.22 moles or 465 STD ft^3 of methane are adsorbed on the sorbent material over a period of 6 hours. The storage tank is then opened to an internal combustion engine. The gas is admitted to the internal combustion engine at a pressure of 0.5 psig. The exhaust gas flows from the internal combustion engine at a temperature of 650° F and 0 psig and flows through the heat exchanger tube in the sorption column. The sorption column is heated to a temperature of 600° F at which temperature the condensables adsorbed therein are deemed to be vaporized and are combined with the fuel from storage tank to be fed to the internal combustion engine. The flow of exhaust gas is then diverted from the sorption column and the fuel gas cools the adsorber column to a temperature of about 80° F. The methane released from the storage tank is sufficient to power a small automobile engine going 30 mph for 3 hours. When the pressure in the storage tank drops to 1 to 5 psig, the storage tank and associated sorption column are removed from service with the internal combustion engine, and a new tank and column are connected to the engine.

The storage tank and sorption column are returned to the flow of inlet gas to readsorb fuel gas in the storage tank to refill the tank.

A pressure tank having a void volume of 3.57 $ft.^3$ is completely filled with finely divided carbon having an actual or solid volume of 0.75 $ft.^3$. The void volume of the carbon thus is 3.57 $ft.^3$ minus 0.75 $ft.^3$ or 2.82 $ft.^3$. The tank is opened to a source of methane at a pressure of 1,000 psi and 80° F. At this pressure, 14.9 lbs. of methane are retained within the pore volume, giving a total of 19.6 pounds of methane stored. In the absence of the carbon in the pressure tank the tank at 1,000 psia will hold 11.0 pounds of methane.

Thus it is seen that an increase of

$$(19.6-11.0)/(11.0)\times(100)=78 \text{ percent}$$

in the amount of methane stored in a given space is achieved.

More methane can be stored in the absorbent containing tank by increasing the pressure, but the increase is not proportional to the pressure increase and while 1,000 psi is used to show the operation of the present invention it is to be understood that the present invention is not limited to a given pressure.

Having thus described the invention, I claim:

1. A method for fueling an internal combustion engine from a low pressure impure methane source consisting of:

a. providing a storage tank containing adsorbent capable of adsorbing methane from said low pressure methane source,
b. providing an adsorption column capable of adsorbing impurities from said low pressure methane source,
c. compressing methane flowing from said low pressure gas source to a higher pressure,
d. flowing said compressed methane through said adsorption column (b) thereby removing impurities,
e. flowing the resulting purified methane of step (d) into said tank of (a),
f. adsorbing said purified methane of step (d) on said adsorbent in said tank (a),
g. connecting said storage tank to the fuel inlet of said internal combustion engine.
h. desorbing methane from said storage tank and flowing said methane to said internal combustion engine.

2. The method of claim **1** wherein said adsorption column is regenerated by:

a. flowing exhaust gas from said internal combustion engine to a heat exchange means located in said adsorption column of step (d),
b. passing methane from said storage tank of (a) through said column heated by the exhaust gas in a reverse direction to that of step (d),
c. combining the regeneration stream containing impurities with the methane flow to said internal combustion engine.

3. The method of claim **1** wherein said impure methane contains at least 85 mole percent methane.

4. The method of claim **1** wherein said impure methane is natural gas.

5. The method of claim **1** wherein said adsorbent in said tank is selected from the group consisting of molecular sieve, silica gel and carbon.

6. The method of claim 1 wherein said adsorption column contains an adsorbent selected from the group consisting of molecular sieve, silica gel and carbon.

7. An apparatus for fueling an internal combustion engine having a fuel inlet and an exhaust comprising:

a. an adsorption containing a suitable adsorbent and having an inlet and an outlet, said adsorption means including heat exchanger means having an inlet and an outlet and means for selectively connecting said exhaust either to said inlet of said heat exchange means or to the atmosphere,

b. a methane storage tank means containing a suitable adsorbent,

c. methane inlet means,

d. means connecting said methane inlet means selectively either to the inlet of said adsorption means or to the fuel inlet of said engine; and,

e. means for connecting said methane storage tank means selectively to the outlet of said adsorption means or to said fuel inlet of said internal combustion engine.

8. The apparatus of claim 7 wherein said means for selectively connecting are at all occurrences valves.

9. The apparatus of claim 7 wherein said means connecting said methane storage tank means selectively either to the outlet of said adsorber means or to said fuel inlet of said internal combustion engine contain pressure regulating valves.

10. The apparatus of claim 7 wherein said methane inlet means includes a compressor.

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