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METHOD AND APPARATUS FOR STORAGE AND TRANSPORTATION OF ACETYLENE

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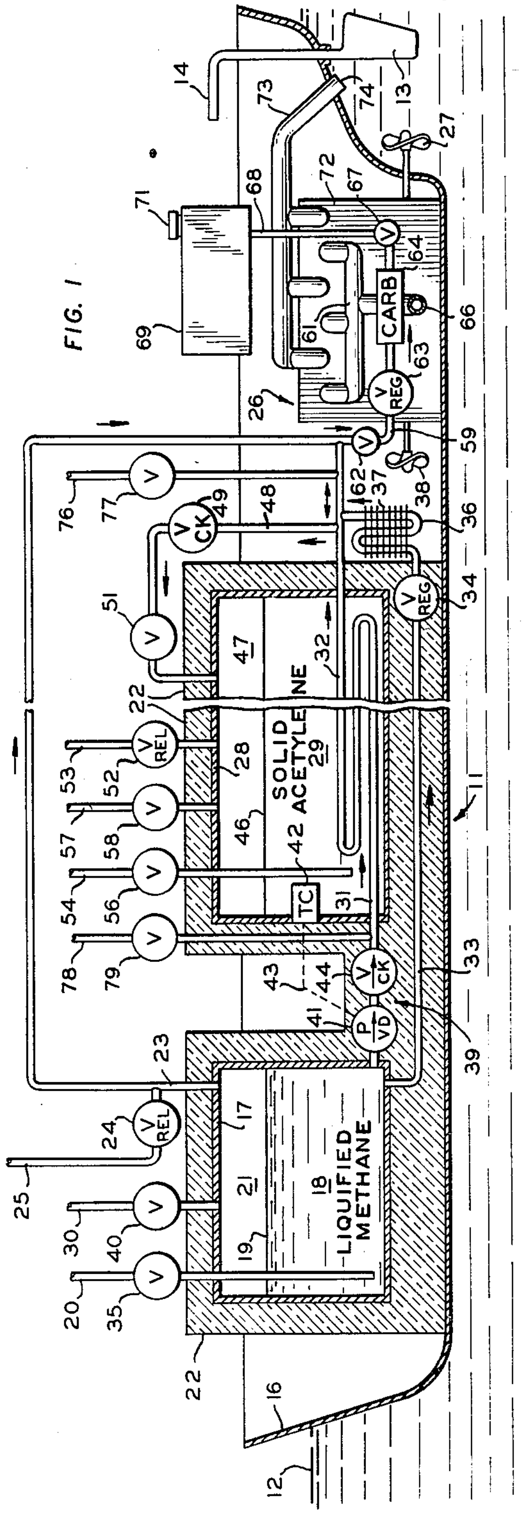

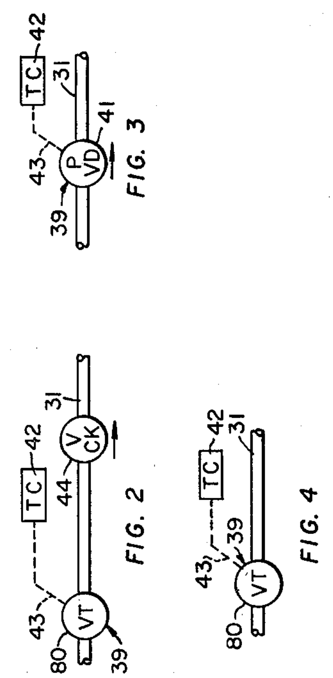

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METHOD AND APPARATUS FOR STORAGE AND TRANSPORTATION OF ACETYLENE

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This invention relates to a method of an apparatus for the storage and transportation of acetylene. More particularly, it relates to the storing and transporting of solid acetylene by vehicle such as a barge or tugboat.

One of the critical problems in large scale acetylene manufacture is the storage of acetylene and its transportation to consumers. These problems arise because of the thermodynamic instability of liquefied and gaseous acetylene. When acetylene decomposes to its elements at 18° C. it liberates 53,500 calories per gram mole, which decomposition is accompanied by a rise in pressure and if rapid can result in detonation. The tremendous force which can be developed during its decomposition characterizes acetylene as belonging to the top group of explosives. Thus, long pipeline transportation of acetylene is hazardous. At the present time, acetylene when used in substantial quantities must be produced where it is consumed because of the commercially infeasible means of transporting it. Expensive conventional methods of compressing acetylene gas into steel cylinders are disadvantageous because the acetylene constitutes a small percentage of the gross weight of the heavy steel cylinders. Transportation of calcium carbide and generation of acetylene therefrom necessitates installation of an expensive acetylene generator by the consumer.

In the past, there have been proposed several methods for storing and transporting solid acetylene. In this physical state, acetylene is intrinsically stable and less hazardous than had been earlier presupposed. The sensitivity of solid acetylene to heat, spark, shock, or friction is slight, and normally it must be set off by a detonating cap. In shattering power and detonating ability solid acetylene is essentially inferior to the usual detonating materials. However, because of the fact that solid acetylene at its sublimation temperature readily liquefies when subjected to an absolute pressure equal to or greater than 1.18 atmospheres, it has been deemed expedient in the past to solidify acetylene from a mixture of gases rather than pure acetylene. The low yield of solid acetylene obtained from the processing of this gaseous mixture is thus commercially disadvantageous.

To obviate the forementioned commercial drawbacks in the storing and transporting of acetylene, we now propose to heat exchange a liquefied fuel gas, such as methane, with acetylene thereby solidifying the latter and to transport it by vehicle, such as a barge or tugboat, and to vaporize the solid acetylene at its point of destination whereby it may be fed directly to the consumer's gas holding equipment. The storing and transporting vehicle is adapted to accommodate a plurality of heat insulated containers some of which will hold the acetylene and the other containers will hold the liquefied fuel gas which will be used both as a refrigerant and as fuel for the vehicle's engine. During transportation, a small amount of the liquefied fuel gas will be vaporized and the vapor utilized to blanket the solid acetylene. When the acetylene is being loaded on the vehicle and

solidified, the liquefied fuel gas vaporized will be recovered by compression facilities at the point of embarkation as part of the liquefaction of the fuel gas.

Accordingly, an object of this invention is to provide method and apparatus for the economical and less hazardous storing and transporting of acetylene.

Another object is to provide method and apparatus for the storing and transporting of solid acetylene utilizing a liquefied fuel gas both as a refrigerant and as a fuel to aid the motive power of said transportation.

A further object is to provide method and apparatus for storing and transporting solid acetylene utilizing a gaseous hydrocarbon to blanket the solid acetylene during its storage and transportation.

Other objects, advantages, and features will become apparent to those skilled in the art from the following discussion, appended claims and the accompanying drawing in which:

Figure 1 is an elevational cross-sectional view in diagrammatic form of a vehicle, specifically a self-propelled barge, embodying one specie of the present invention; and

Figures 2, 3 and 4 are diagrammatic views of other forms of temperature controls which can be substituted for the specific temperature control shown in Figure 1.

Our invention is illustrated in the accompanying drawing, Figure 1, in which is shown an elevational cross-sectional view in diagrammatic form of a vehicle, specifically a self-propelled barge, embodying the present invention. However, it is to be understood that the present invention involves storage in, and/or transport by means of any type of vehicle, such as an automobile land vehicle, railroad vehicle, ship, submarine, aircraft, or the like. For purposes of illustrating the invention, however, a polix showing of all possible modifications of our invention has been avoided and we have merely set forth the best mode contemplated for carrying out our invention to enable persons skilled in the art to practice the same. Since transportation by marine vehicle, such as a barge, is the most economical mode of transportation per ton per mile when the cost factor of time is considered small, the present invention will be described in the terms of embodiments selected from that art, but the practice of this invention is not necessarily limited thereto.

In Figure 1 is shown a vehicle, specifically a self-propelled barge **11**, floating on the surface **12** of a body of water over which it is desired to transport acetylene by marine transportation. Barge **11** is naturally provided with a rudder **13**, tiller **14**, hull **16**, and such other equipment and appurtenances as are commonly associated with vehicles of this type and further discussion or illustration of the same will not be set forth.

Mounted anywhere in the hull **16** of barge **11** is a tank **17** adapted to contain a liquefied fuel gas **18**, such as methane, having a liquid surface **19**, and a vapor **21** of said liquefied fuel gas **18** above the same at a low but superatmospheric pressure. By low but superatmospheric pressure is meant any pressure between atmospheric and 100 p.s.i.g. Thus, because of the low but superatmospheric pressure employed, the wall of the tank **17** need not be excessively thick.

Tank **17** is constructed of any suitable metal, such as carbon or alloy steel, and is supplied with a suitable layer of heat insulation material **22**, either as an external layer, as shown, or as an internal layer and/or an external layer as taught by the patent to Jackson 2,470,986 of May 24, 1949. The heat insulation material may be any heat insulation material known in the refrigeration art such as glass wool, cork, or other materials mentioned in the patent to Jackson, although balsa wood in the form of an inner layer only is preferred when tank 17 is filled with liquefied natural gas, or liquefied methane.

Tank 17 may be supplied with the usual supply or withdrawal line 20, vapor withdrawal and supply line 30, and gas relief stack 25, controlled respectively by shut-off valves 35 and 40 and pressure relief valve 24, along with such other appurtenances and devices as are common to the prior art relating to such tanks, such as liquid level gauges, thermometers, etc., and which will be obvious or may seem necessary or desirable to the engineer designing the same.

No matter how thick insulation 22 is, the difference between the ambient atmospheric temperature and the boiling point of liquid 18 is so great that some heat is going to be leaking in through the insulation 22 and causing evaporation of the liquid 18 in the form of gas 21, and if not used or discharged the pressure of this gas 21 will rise in line 23 until it opens pressure relief valve 24, which may be set to open in any desired pressure from a few inches of water pressure above atmospheric to about 100 p.s.i.g. depending upon the working pressure for which tank 17 is designed in the practice of the present invention, one particular pre-determined pressure for operating being selected. It is preferred however, to not have relief valve 24 open, and this is accomplished by having pipe 23 conduct the fuel gas 21 to an engine generally designated as 26 where it is employed as fuel to contribute to the transportation of the vehicle 11, for example by rotating screw propeller 27 in the species shown in the drawing. The cold gas 21 warms up going through pipe 23.

Although the drawing illustrates an internal combustion engine 26 in which the fuel is consumed, any suitable power plant or engine can be employed to propel the barge 11 such as a diesel engine or an engine comprising a steam boiler and steam turbine. Moreover, although a self-propelled barge 11 has been illustrated, it is also within the scope of this invention to employ a barge which is propelled through a body of water by reason of it being attached to a tugboat (not shown) by means of a towing cable suitably secured to the respective vehicles. In this latter case, the power-plant or engine propelling the tugboat, which in turn tows the barge, can use as fuel the liquefield fuel gas contained in a tank, similar to the tank 17 of barge 11, by providing suitable fuel lines extending between the two vehicles and other equipment and appurtenances well known in the prior art.

Referring now again to the drawing, a second tank 28 is provided on barge 11, which is constructed in all respects similar to tank 17 described above. Tank 28 is provided with the same type of heat insulation material outside and/or inside, and, as shown in the drawing, this insulation may be an extension of insulation around tank 17. Tank 28 is to contain solid acetylene 29 during storage and transportation and its insulation 22 must be sufficiently thick to maintain a temperature in the range of −85° C. to −156° C. When the liquefied fuel gas 18 employed is liquefied methane which has a boiling point of −161.5° C., the thickness of the insulation 22 for tank 28 may be less than that for tank 17 since the melting point of solid acetylene is −81.8° C. However, it is preferred to maintain that thickness around tank 28 which will require most of the fuel utilized by engine 26 to be supplied through line 31 by evaporation of liquid 18 in indirect heat exchanger 32. The thickness of insulation employed around tank 18 will be such that the amount of gas 21 evaporated from liquid 18 will be insufficient to meet the normal fuel requirements of engine 26. When the total amount of fuel being supplied to engine 26 by lines 23 and 31 is still insufficient to supply the normal fuel requirements of the engine 26, liquid fuel gas 18 may be withdrawn by gravity through line 33 or by means of a pump (not shown), through a pressure regulating valve 34 maintaining a constant pressure downstream, into an indirect heat exchanger 36 to which sufficient heat may be supplied to evaporate said portion of liquefied fuel gas 18 to form the required amount of gas needed as fuel for engine 26. The heat exchange at 36 is preferably with the atmosphere, as shown, aided by conventional heating fins 37 and/or fan 38. Fan 38 if employed is driven by engine 26 or any suitable independent source of power (not shown). Other means for supplying heat to heat exchanger 36 can be employed in this invention, such as heat exchange with the water 12, or with an intermediate heat exchange fluid passed in further heat exchange with either the atmosphere or the water.

Line 31 communicating between tank 17 and engine 26 is provided upstream of heat exchange portion 32 with suitable flow control means, generally designated as 39, comprising variable delivery pump 41 driven by any suitable source of power, the delivery of which is selected and controlled by temperature control 42 through any suitable control circuit 43, a large number of which are available in the prior art, employing thermocouples, thermisters, or any mechanical or electrical thermostat means (not shown in detail). While not necessary, it is desirable to employ a check valve 44 to obviate any temporary reversal of flow in line 31 which might accidentally occur, as it is not desirable for any fluid to return to tank 17 bearing any appreciable amount of heat with it. Flow control system 39 may employ a throttle valve 80, Figure 2, in place of the variable delivery pump 41 of Figure 1. Because of the pressure equalization through line 23, this latter fuel control system of Figure 2 will operate by gravity feed due to the difference in elevation of surface 19 of liquefied fuel gas 18 and the point where the latter becomes discontinuous in heat exchanger 32 due to evaporation. In a third modification, Figure 3, of the flow control system 39, the check valve 44 of Figure 1 can be eliminated. In a fourth modification, Figure 4, only a throttle valve 80 may be employed.

Heat exchanger 32 is preferably located inside tank 28 submerged in solid acetylene 29 to remove the heat leaking in from the atmosphere through insulation 22 by evaporation of liquid 18 inside pipe 32. However any other disposition of pipe 32, as along the bottom of tank 28 (not shown) which places solid acetylene 29 in indirect heat exchange with the fluid in pipe 32 is equivalent in the practice of the invention.

Solid acetylene 29 has a surface 46 above which is a space 47 into which it can sublime. To insure that there is not a possibility of the formation of an explosive or combustible acetylene-air mixture, that is to prevent the ingress of air into space 47 and/or the egress of acetylene gas from tank 28 into the atmosphere, we propose to charge space 47 with fuel gas, such as methane vapor, in order to completely blanket solid acetylene 29. That amount of gaseous acetylene which does result from the sublimation of solid acetylene 29 during storage and transportation (which will be very minor due to the efficiency of the refrigeration of tank 28) will thus be diluted with fuel gas supplied from heat exchanger 32 through line 48 controlled by check valve 49 and shut-off valve 51. Normally the pressure of the acetylene-fuel gas mixture in space 47 is insufficient to ever overcome pressure relief valve 52 in gas stack 53. This pressure relief valve 52 is adapted to release gas mixture in space 47 if the pressure rises above atmospheric in order to prevent solid acetylene 29 from passing to the liquid state and thus prevent explosion of tank 28 in case of some unforeseen emergency. Tank 28 may also be provided with acetylene gas supply and withdrawal line 54 containing shut-off valve 56, vapor supply and withdrawal line 57 controlled by shut-off valve 58, and such other appurtenances known in the prior art for such tanks as may be deemed desirable.

Lines 23, 31 and 33 are connected together and supply gas to engine 26 through line 59. While line 59 can lead directly to the intake manifold 61 of engine 26, it is preferred to provide line 59 with a shut-off valve 62, and a pressure regulating valve 63 providing a constant pressure downstream and then pass the gas to the intake manifold either directly, or through a carburetor 64. While a single valve 63 is shown for reducing gas pressure to a constant downstream pressure, this may be done in one stage as shown, or there can be a plurality of such valves in series to reduce the pressure by stages (not shown because such multistage reduction is very old in this art). By setting the constant pressure downstream of regulating valve 63 slightly below atmospheric pressure, loss of gas through the air intake 66 of manifold 61 is obviated, as gas will not flow unless the engine is turning over with resulting vacuum in the intake manifold.

While carburetor 64 is not essential, as gas line 59 could be connected in direct communication with intake manifold 61, and valve 62 used as a throttle valve, the use of carburetor 64 is preferable to act as a throttle valve in controlling the speed of engine 26. Also carburetor 64 has an additional function in that shut-off valve 62 can be closed if it is not desired to use gas 21, or if gas 21 is exhausted, and then shutoff valve 67 may be open and an auxiliary fuel such as gasoline, may be supplied to the carburetor 64 through line 68 from fuel tank 69 having the usual filling cap 71. This is an emergency feature in the ship 11, but if used in a tugboat towing a non-self-propelled barge an auxiliary fuel is essential when the tug is disconnected from this type of barge.

The burned fuel from the cylinder block 72 of engine 32 is exhausted through exhaust manifold 73 in the usual manner, and may be discharged a slight distance under water through outlet 74 as shown in order to muffle the noise of the same.

While in theory it would be most economical to operate without carburetor 64 and auxiliary fuel tank 69 by merely running pipe 59 directly into communication with intake manifold 61, and rely on foresight in always having sufficient liquefied fuel gas 18 left to return to base, after discharging solid acetylene 29 and as much of liquefied fuel gas 18 as desired and otherwise completing the trip, it is much preferred to have the auxiliary fuel tank 69 and carburetor 64. If anything unexpected occurs to delay the ship at some isolated spot in the river, due to floods, storms, or other unexpected contingencies, or accidents, it is a lot easier to carry tins of gasoline from a nearby service station to the ship to replenish auxiliary tank 69, than it is to make a special trip with very special storage and refrigeration equipment in order to replace liquefied fuel gas 18, although of course the latter could be done.

As stated hereinbefore, transportation of solid acetylene may be accomplished by a non-self-propelled barge towed by a tugboat. This second mode of transportation is similar to that taught by Robert E. Sattler and J. W. Davison in a copending application, Serial No. 498,322, filed March 31, 1955, now Patent No. 2,695,937 dated June 18, 1957. In this latter modification, a towed barge contains all of the tanks and other equipment shown upstream of valve 62 in the drawing and fuel line 59 is extended by means of a flexible fuel supply line to a tugboat which tows the barge and utilizes the fuel in the same manner as set forth in relation to the utilization of fuel by engine 26 of self-propelled barge 11 and it is not believed necessary to repeat the details of such operation here. While the preferred method of storing and transporting solid acetylene is in tanks carried by vehicle, such as a self-propelled barge, it is within the scope of this invention to transport it in a vessel of small size and weight in the refrigerated condition and at the requisite pressure, maintaining the fuel gas blanket, preferably methane vapor, as hereinbefore described. The solid acetylene in this case may be in the form of blocks, finely divided, or any other form suitable for use. In some systems where acetylene is used, for instance in polymerization processes, it would be particularly advantageous to store and/or transport acetylene in this manner because the fuel gas employed as a blanket, such as methane vapor, can be tolerated by many systems whereas a gas such as carbon dioxide blanket for example, such as disclosed in the prior art, would deleteriously affect many systems.

Operation

In the operation of the invention shown in the drawing, liquid natural gas 18 is maintained in a refrigerated condition in heat insulated tank 17 at a low superatmospheric pressure of less than 100 p.s.i.g., but preferably at not more than 5 to 10 p.s.i.g., at a temperature of its boiling point at that pressure of about −160° C. Pressure relief valve 24 is set at the desired relief pressure, say 5 p.s.i.g. As tank 17 will have not been built to stand much more pressure than that for which relief valve 24 is set, it is the primary function of the system that pressure in lines 23, 31 and 33 will not go over said relief pressure, say 5 p.s.i.g. Valve 34 is set to open only when the pressure in 36 drops a predetermined amount below said 5 p.s.i.g., for example 4 p.s.i.g. Valve 63 only opens when the engine 26 is running and there is a vacuum in intake manifold 61 due thereto. Temperature control 42 is set to pump first liquid natural gas 18 through line 32 to maintain solid acetylene 29 in refrigerated condition in tank 28 at a predetermined temperature at which the vapor pressure in space 47 will be less than 1.18 atmospheres or will always be less than the setting of relief valve 52.

It is therefore obvious that if the heat insulation on tank 28 is designed to permit about the right rate of heat leakage, that the fuel in line 59 for engine 26 will be supplied essentially by liquefied fuel gas 18 evaporating in coil 32 in quantities sufficient to keep solid acetylene 29 cool enough to keep it from subliming and relief valve 52 will remain closed so that none of acetylene-methane gas in space 47 is ever lost, except if the pressure should ever exceed atmospheric. Some small amount of this fuel will be supplied to line 59 by line 23 due to minor evaporation in tank 17. If this supply is greater than the demand of engine 26, the pressure in 23 will go up above 5 p.s.i.g., and relief valve 24 will vent the excess amount to the atmosphere at a safe point 25. If this supply is less than the demand of the engine 26, the pressure in line 23 will go down below 4 p.s.i.g. and valve 34 will open allowing liquefied fuel gas 18 to flow into coils 36 and evaporate to supply the additionally needed fuel.

Acetylene supply line 54 is adapted to be coupled to acetylene supply facilities (not shown) at the point of embarkation of barge 11, which facilities are well known in the prior art and need not be set forth here. When acetylene gas is being loaded in tank 28 of barge 11 from embarkation acetylene supply facilities, tank 28 is initially charged with gas vapor from line 48 and as solidification of the acetylene gas progresses, the gas vapor is withdrawn from line 32 through line 76 provided with shut-off valve 77 and recovered as part of the liquefaction of the fuel. When the tank 28 is sufficiently loaded with pay cargo, gas vapor is again supplied to engine 26 to aid in the transportation of the solid acetylene 29 by barge 11. Upon barge 11 reaching its point of destination, the heat exchange in line 32 is discontinued and valves 41, 34, 51 and 62 closed, whereupon any suitable heat exchange medium, which may be ambient air for example, will be passed through heat exchange line 32 (after purging of gas vapor therein) from any suitable heat supply facilities commonly used at disembarkation parts. Such heat exchange medium is introduced into line 78 which is provided with shut-off valve 79 and withdrawn by line 76 provided with shut-off valve 77. The passing of heat exchange medium through lines 78, 32 and 76 is such that it causes the solid acetylene 29 to sublime and the gaseous acetylene is removed from tank 28 by acetylene withdrawal line 57 to acetylene storage facilities at the point of destination. Purging of residual acetylene gas in tank 28 may be accomplished by opening shut-off valve 51 thus introducing gas vapor once again into tank 28 through line 48. Although the embodiment of the present invention shown in the drawing illustrates means whereby the heat exchange facilities at the point of destination are used to heat the solid acetylene and cause it to sublime, it is within the scope of this invention to employ separate heat exchange coils in tank 28 for this purpose. It is also within the scope of this invention to utilize the ambient temperature at the point of destination as means to cause the solid acetylene to sublime.

While a number of embodiments have been shown for purposes of illustration, the invention obviously is not limited thereto. For example, while tanks 17 and 22 are shown, described, and claimed, as single tanks, obviously in details of vehicle construction it will sometimes be better structural design to use a plurality of tanks connected in parallel, or connected in series, for either, or both, of tanks 17 and 28. As this is an obvious expedient it has not been shown in the drawing. It is also within the scope of this invention to employ as fuel gas any fuel gas which can be liquefied and has a boiling point substantially lower than the sublimation point of acetylene, although methane is generally preferred.

Having described our invention we claim:

1. The method of storing acetylene in its solid state which comprises enclosing solid acetylene in a heat insulated, gas-tight vessel, maintaining said solid acetylene in a refrigerated condition during storage below its sublimation point by passing liquefied fuel gas in indirect evaporative heat exchange with said solid acetylene, said liquefied fuel gas having a boiling point substantially below the sublimation point of said solid acetylene, and passing a portion of fuel gas resulting from said indirect evaporative heat exchange into said vessel thereby blanketing said solid acetylene during said storage with an atmosphere of fuel gas at substantially atmospheric pressure.

2. The method according to claim 1 wherein said fuel gas is methane.

3. The method of transporting acetylene in its solid phase, comprising storing solid acetylene in a first heat insulated zone at substantially atmospheric pressure, storing liquefied fuel gas in a second heat insulated zone at a low superatmospheric pressure, said liquefied fuel gas having a boiling point substantially below the sublimation point of said solid acetylene, maintaining said solid acetylene in the solid phase by passing a sufficient first amount of said liquefied fuel gas in indirect evaporative heat exchange with said solid acetylene, burning a portion of the resulting evaporated fuel gas as fuel for an engine, placing a portion of said fuel gas as a gaseous blanket for said solid acetylene in said first heat insulated zone, burning that portion of said liquefied fuel gas as is evaporated by ambient atmospheric heat leaking into said second zone as additional fuel for said engine, withdrawing a sufficient second amount of said liquefied fuel gas from said second zone to supply said engine with enough fuel to provide sufficient power for said transport, vaporizing said second amount of liquefied fuel gas enroute to said engine, and applying the power developed by said engine to transport said zones as a unit.

4. The method of transporting acetylene in its solid phase, comprising storing solid acetylene in a first heat insulated zone at substantially atmospheric pressure, storing liquefied fuel gas in a second heat insulated zone at low superatmospheric pressure, said liquefied fuel gas having a boiling point substantially below the sublimation point of said solid acetylene, maintaining said solid acetylene in the solid phase by passing a sufficient first amount of said liquefied fuel gas in indirect evaporative heat exchange with said solid acetylene, burning a portion of the resulting evaporated fuel gas as fuel for an engine, placing a portion of said fuel gas as a gaseous blanket for said solid acetylene in said first heat insulated zone, withdrawing a sufficient second amount of said liquefied fuel gas from said second zone to supply said engine with enough fuel to provide sufficient power for said transport, vaporizing said second amount of liquefied fuel gas enroute to said engine, and applying the power developed by said engine to transport said zones as a unit.

5. The method of transporting acetylene in its solid phase, comprising storing solid acetylene in a first heat insulated zone at substantially atmospheric pressure, storing liquefied fuel gas in a second heat insulated zone at low superatmospheric pressure, said liquefied fuel gas having a boiling point substantially below the sublimation point of said solid acetylene, maintaining said solid acetylene in the solid phase by passing a sufficient first amount of said liquefied fuel gas in indirect evaporative heat exchange with said solid acetylene, burning a first portion of the resulting evaporated fuel gas as fuel for an engine, placing a portion of said fuel gas as a gaseous blanket for said solid acetylene in said first heat insulated zone, burning that portion of said liquefied fuel gas as is evaporated by ambient atmospheric heat leaking into said second zone as additional fuel for said engine, and applying the power developed by said engine to transport said zones as a unit.

6. The method of transporting acetylene in its solid phase, comprising storing solid acetylene in a first heat insulated zone at substantially atmospheric pressure, storing liquefied fuel gas in a second heat insulated zone at low superatmospheric pressure, said liquefied fuel gas having a boiling point substantially below the sublimation point of said solid acetylene, maintaining said solid acetylene in the solid phase by passing a sufficient first amount of said liquefied fuel gas in indirect evaporative heat exchange with said solid acetylene, placing a portion of the resulting evaporated fuel gas as a gaseous blanket for said solid acetylene in said first heat insulated zone, burning a portion of said fuel gas as fuel for an engine, and applying the power developed by said engine to transport said zones as a unit.

7. The method of claim 6 in which said fuel gas is methane.

8. In combination, a first heat insulated tank, a second heat insulated tank, a vehicle upon which said tanks are mounted for movement as a unit, said vehicle propelled by an engine, a first vapor line connecting the upper part of said first tank in communication with the intake of said engine, a pressure relief valve in said first vapor line, a first liquid withdrawal line connecting the lower part of said first tank with said engine intake, a regulating valve for maintaining a constant pressure downstream in said first liquid line, an indirect heat exchanger associated with said first liquid line downstream of said regulating valve and upstream of said engine intake, a second liquid withdrawal line connecting the lower portion of said first tank in communication with said engine intake, flow control means in said second liquid line, said second liquid line downstream of said flow control means and upstream of said engine intake having a heat exchange portion associated with said second tank, temperature sensitive means in said second tank connected to control the operation of said flow control means, a second vapor line connecting that portion of said second liquid line downstream of said heat exchange portion with the upper part of said second tank, said second line having a shut-off valve and a check valve, and a heat exchange means associated with said second tank.

9. In combination, a first heat insulated tank, a second heat insulated tank, a vehicle upon which said tanks are mounted for movement as a unit, said vehicle propelled by an engine, a first liquid withdrawal line connecting the lower part of said first tank with said engine intake, a regulating valve for maintaining a constant pressure downstream in said first liquid line, an indirect heat exchanger

associated with said first liquid line downstream of said regulating valve and upstream of said engine intake, a second liquid withdrawal line connecting the lower portion of said first tank in communication with said engine intake, flow control means in said second liquid line, said second liquid line downstream of said flow control means and upstream of said engine intake having a heat exchange portion associated with said second tank, temperature sensitive means in said second tank connected to control the operation of said flow control means, a vapor line connecting that portion of said second liquid line downstream of said heat exchange portion with the upper part of said second tank, said vapor line having a shut-off valve and a check valve, and a heat exchange means associated with said second tank.

10. In combination, a first heat insulated tank, a second heat insulated tank, a vehicle upon which said tanks are mounted for movement as a unit, said vehicle propelled by an engine, a first vapor line connecting the upper part of said first tank in communication with the intake of said engine, a pressure relief valve in said first vapor line, a liquid withdrawal line connecting the lower portion of said first tank in communication with said engine intake, flow control means in said liquid line, said liquid line downstream of said flow control means and upstream of said engine intake having a heat exchange portion associated with the said second tank, temperature sensitive means in said second tank connected to control the operation of said flow control means, a second vapor line connecting that portion of said liquid line downstream of said heat exchange portion with the upper part of said second tank, said second vapor line having a shut-off valve and a check valve, and a heat exchange means associated with said second tank.

11. In combination, a first heat insulated tank, a second heat insulated tank, a vehicle upon which said tanks are mounted for movement as a unit, said vehicle propelled by an engine, a liquid withdrawal line connecting the lower portion of said first tank in communication with said engine intake, flow control means in said liquid line, said liquid line downstream of said flow control means and upstream of said engine intake having a heat exchange portion associated with said second tank, temperature sensitive means in said second tank connected to control the operation of said flow control means, a vapor line connecting that portion of said liquid line downstream of said heat exchange portion with the upper part of said tank, said vapor line having a shut-off valve and a check valve, and a heat exchange means associated with said second tank.

12. In combination, a first heat insulated tank adapted to contain liquefied fuel gas together with an atmosphere of vaporized fuel gas at low superatmospheric pressure, a second heat insulated tank adapted to store solid acetylene together with an atmosphere of vaporized fuel gas at atmospheric pressure, a vehicle upon which said tanks are mounted for movement as a unit, said vehicle propelled by an engine, a first vapor line operatively connected to conduct said vaporized fuel gas in said first tank to the intake of said engine, a liquid withdrawal line operatively connected to conduct some of said liquefied fuel gas in said first tank to said engine intake, said liquid line associated with a first indirect heat exchanger upstream of said engine intake, a second indirect heat exchanger associated with said second tank and adapted to vaporize said liquefied fuel gas supplied from said first tank whereby said solid acetylene is maintained in the solid state, said second heat exchanger operatively connected to conduct a portion of the resulting vaporized fuel gas to said engine intake, a second vapor line operatively connected to conduct a portion of said resulting vaporized fuel gas to said second tank whereby said solid acetylene is blanketed with vaporized fuel gas, and a third heat exchange means associated with said second tank whereby said solid acetylene can be sublimed.

13. In combination, a first heat insulated tank adapted to contain liquefied fuel gas together with an atmosphere of vaporized fuel gas at low superatmospheric pressure, a second heat insulated tank adapted to store solid acetylene together with an atmosphere of vaporized fuel gas at atmospheric pressure, a vehicle upon which said tanks are mounted for movement as a unit, said vehicle propelled by an engine, a liquid withdrawal line operatively connected to conduct some of said liquefied fuel gas in said first tank to said engine intake, said liquid line associated with a first indirect heat exchanger upstream of said engine intake, a second indirect heat exchanger associated with said second tank and adapted to vaporize said liquefied fuel gas supplied from said first tank whereby said solid acetylene is maintained in the solid state, said second heat exchanger operatively connected to conduct a portion of the resulting vaporized fuel gas to said engine intake, a second vapor line operatively connected to conduct a portion of said resulting vaporized fuel gas to said second tank whereby said solid acetylene is blanketed with vaporized fuel gas, and a third heat exchange means associated with said second tank whereby said solid acetylene can be sublimed.

14. In combination, a first heat insulated tank adapted to contain liquefied fuel gas together with an atmosphere of vaporized fuel gas at low superatmospheric pressure, a second heat insulated tank adapted to store solid acetylene together with an atmosphere of vaporized fuel gas at atmospheric pressure, a vehicle upon which said tanks are mounted for movement as a unit, said vehicle propelled by an engine, a first vapor line operatively connected to conduct said vaporized fuel gas in said first tank to the intake of said engine, an indirect heat exchanger associated with said second tank and adapted to vaporize said liquefied fuel gas supplied from said first tank whereby said solid acetylene is maintained in the solid state, said heat exchanger operatively connected to conduct a portion of the resulting vaporized fuel gas to said engine intake, a second vapor line operatively connected to conduct a portion of said resulting vaporized fuel gas to said second tank whereby said solid acetylene is blanketed with vaporized fuel gas, and a heat exchange means associated with said second tank whereby said solid acetylene can be sublimed.

15. In combination, a first heat insulated tank adapted to contain liquefied fuel gas together with an atmosphere of vaporized fuel gas at low superatmospheric pressure, a second heat insulated tank adapted to store solid acetylene together with an atmosphere of vaporized fuel gas at atmospheric pressure, a vehicle upon which said tanks are mounted for movement as a unit, said vehicle propelled by an engine, an indirect heat exchanger associated with said second tank and adapted to vaporize said liquefied fuel gas supplied from said first tank whereby said solid acetylene is maintained in the solid state, said heat exchanger operatively connected to conduct a portion of the resulting vaporized fuel gas to the intake of said engine, a vapor line adapted to conduct a portion of said resulting vaporized fuel gas to said second tank whereby said solid acetylene is blanketed with vaporized fuel gas and heat exchange means associated with said second tank whereby said solid acetylene can be sublimed.

16. The method of storing acetylene in a solid state which comprises introducing a gas comprising essentially acetylene gas into a heat insulated, gas-tight vessel and passing liquefied fuel gas in indirect evaporative heat exchange relation with said acetylene gas in said vessel so as to solidify said acetylene gas, maintaining the resulting solid acetylene in a refrigerated condition below its sublimation point during storage in said vessel by continuing to pass said fuel gas in evaporative heat exchange with said solid acetylene, and blanketing said solid acetylene during said storage with an atmosphere of said fuel gas in its vapor form at substantially atmosphere

pressure, said fuel gas having a boiling point substantially below the sublimation point of said solid acetylene.

17. The method according to claim 16 wherein said fuel gas is methane.

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CERTIFICATION OF CORRECTION

Patent No. 2,938,359 May 31, 1960

Joseph R. Cobb, Jr., et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 9, line 48, before "tank" insert -- second --.

Signed and sealed this 15th day of August 1961.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents