April 8, 1947. O. R. ANDERSON 2,418,446

METHOD OF AND APPARATUS FOR HEATING LIQUEFIED GAS FUEL

Filed Oct. 20, 1938 2 Sheets-Sheet 1

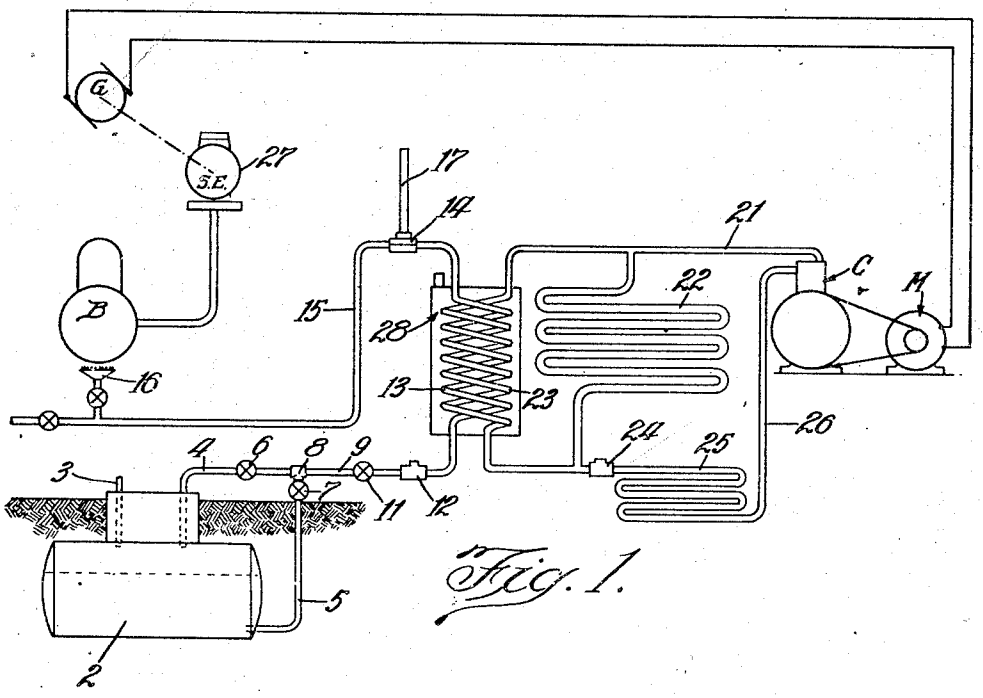


Fig. 1.

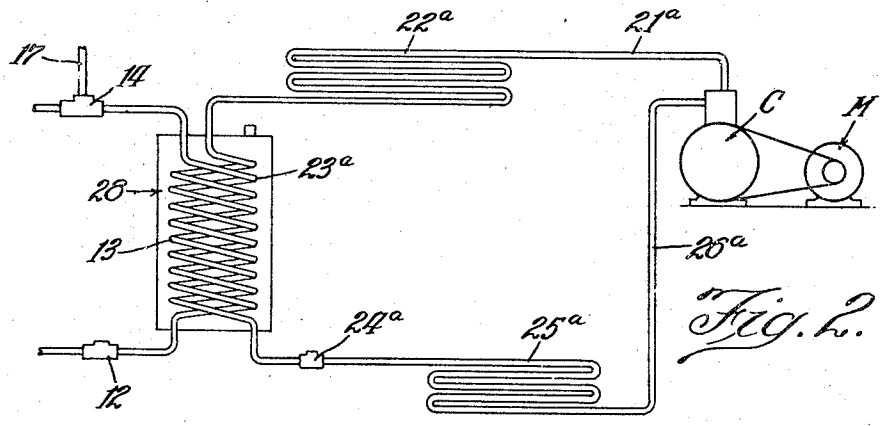
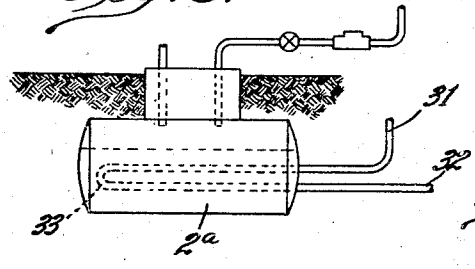


Fig. 2.

Fig. 3.



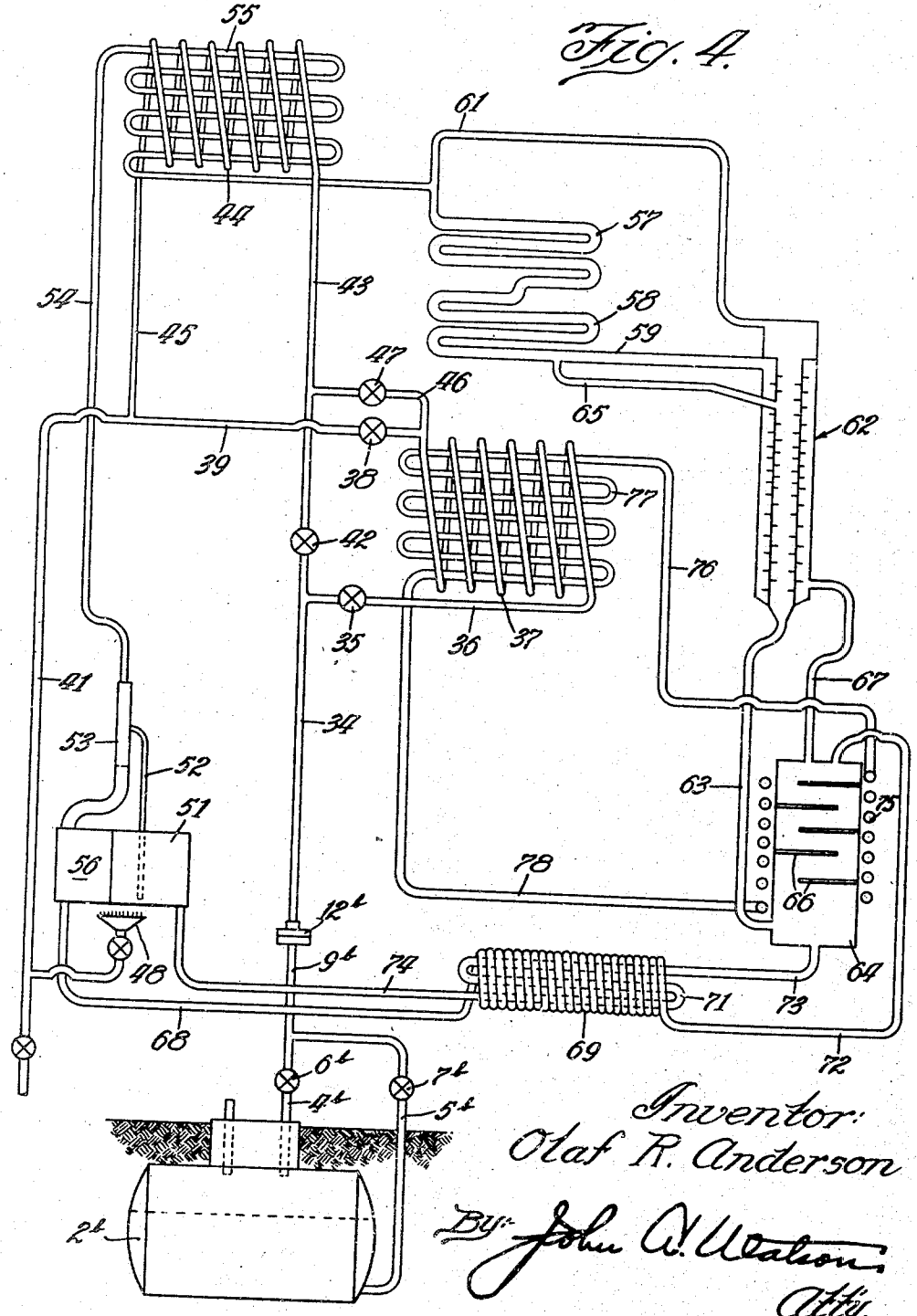
Inventor:
Olaf R. Anderson
By: John A. Watson
Atty.

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Fig. 4.



Inventor:
Olaf R. Anderson
By: John A. Watson
Atty.

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UNITED STATES PATENT OFFICE

2,418,446

METHOD OF AND APPARATUS FOR HEATING LIQUEFIED GAS FUEL

Olaf R. Anderson, Chicago, Ill., assignor, by mesne assignments, to The Bastian-Blessing Company, Chicago, Ill., a corporation of Illinois

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20 Claims. (Cl. 62—1)

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This invention pertains both to fuel supply systems and to refrigeration systems and, more particularly, to utilization of waste heat from the refrigeration system, for the purpose of either vaporizing liquid fuel to form a combustible vapor or gas or for the purpose of heating or superheating the pre-formed fuel vapor thereby to improve the combustion and other characteristics thereof, the refrigerant being simultaneously and correspondingly cooled for condensation or other purposes.

Fuel systems employing liquified gas such as propane, butane and mixtures thereof, generally utilize an underground storage tank or reservoir from which the fuel, either in a liquid or in a vaporized state, is piped to a furnace or range or other place of use. Since the invention is primarily of importance in connection with systems in which the fuel is in a gaseous or vapor form when burned further reference to systems in which the fuel is liquid at the burner, will be omitted.

The liquid fuel may be supplied to the storage tank or reservoir by tank truck and is held under pressure therein subject to use. Earth heat is sometimes the sole means to effect vaporization of the liquid fuel but where the earth heat may be insufficient, auxiliary means such as a steam or hot water coil in the bottom portion of the storage tank or a pilot heater beneath the tank may be used to supply the heat needed to effect vaporization and the pressure for delivery. Sometimes the home water supply line is run through or in other heat transfer relation to the liquid fuel in the reservoir thereby to deliver its heat to effect vaporization of the fuel. None of these methods is wholly satisfactory and most of them are unsafe or dangerous or involve expensive equipment including controls.

Since the gas demands of the consumer vary considerably, neither steam nor hot water coils nor a pilot heater may be used without complicated and expensive safety controls and if steam or hot water is used the expense of a pump to return condensate or to circulate the hot water becomes a practical necessity. Where the house water supply is used to supply the liquid fuel with heat, other problems are introduced. If too much heat is absorbed from any given volume of water by vaporization of the fuel, as may be the case when considerable gas and very little water is being used, the water line may freeze and burst with attendant difficulties including the possibility of gas or liquid fuel in the water line.

But vaporization of the liquid fuel in the storage reservoir is only a part of the problem for the vapor is so cold (propane vaporizes around —40° C. and F. and butane at about 0° C. or 32° F.) that it does not burn efficiently and butane may separate out of a mixture of propane and butane and this separation may occur anywhere in the line, by condensation thereof. Furthermore the butane may not be vaporized in proportion to the propane from the mixture in the reservoir or may not volatilize at all. Accordingly if the air-gas mixture ratio at the burner is set for a definite fuel mixture, any variation in the fuel proportions may produce undesirable flame characteristics and may require constant readjustments of the air-gas mixture.

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Accordingly one of the primary objects of the invention is to provide a simple but efficient and effective method of and a system for supplying the requisite heat to effect homogeneous or proportional vaporization of liquid fuels such as those above mentioned, to effect heating or superheating of the fuel vapors whereby to increase combustion efficiency and to reduce or eliminate condensation of the heavier fuel constituents, to reduce fire and explosion hazards, and, in short to obviate or reduce the various difficulties heretofore encountered in the vaporization and combustion of liquid fuels of the types mentioned.

The invention is also concerned with the more efficient cooling and condensing of refrigerants. The ordinary household refrigerator offers many problems to the engineer from the standpoint of dissipation of the heat absorbed by the refrigerant in cooling the box and the internal heat of work done on the refrigerant. The problems are similar in both the compressor type and the absorber type refrigerating systems—in each case there is considerable waste heat which is difficult to dissipate. Most household refrigerator condensers operate at temperatures considerably above normal room temperatures and, accordingly, are inefficient. Furthermore, the dissipation of heat from the refrigerant is not only an economic loss but, when dissipated into a room, may make the temperature of the room uncomfortably high.

Therefore, another object of the invention resides in a method of and in a system by which the internal and absorbed heat of the refrigerant may be removed rapidly and efficiently therefrom and may be utilized to carry out the first object above specified, all to the end that better and more efficient refrigeration may be effected and that a more efficient and satisfactory liquid-to-vapor or gaseous fuel system may be provided.

Many other objects as well as the advantages and uses of the invention will be appreciated and understood after reading the following description and claims and after viewing the several embodiments illustrated in the accompanying drawings in which:

Fig. 1 is a diagrammatic view of a liquid-to-vapor fuel system combined with a compressor type refrigeration system, in illustration of one preferred arrangement in which a heat exchanger is placed in parallel with the condenser of the refrigerant system.

Fig. 2 is a view similar to the view of Fig. 1 but illustrating a heat exchanger in series with the refrigerant condenser, the view being simplified by omission of other parts already shown in Fig. 1.

Fig. 3 is a view of a part of a liquid-to-vapor fuel system similar to the system of Fig. 1 but showing a different means whereby to transfer the waste heat of refrigeration to the fuel, the primary function of the heat, in this case, being to effect homogeneous vaporization of the liquid fuel, and

Fig. 4 is a schematic view of one type of absorption refrigeration system illustrating one way by which a liquid-to-vapor fuel system may be combined therewith in carrying out the objects of the invention.

The apparatus diagrammatically illustrated in Fig. 1 includes a liquid-to-vapor fuel system and a compressor type refrigeration system interrelated in heat exchange and operation. Such a system may be considered as adapted for rural gas supply and refrigeration purposes or for small commercial plants but is adaptable to other types of use. An underground liquid fuel storage tank 2 is provided with a fill pipe 3, which in turn may be provided with a safety pressure vent, a vapor outlet pipe 4 and a liquid outlet pipe 5, the normal top level of the liquid fuel in the tank being indicated by the horizontal dotted line. The pipe lines 4 and 5 may be provided with shut off valves 6 and 7, respectively, and may join through a T connection 8 with a common supply line 9 in which a shut off valve 11 and either a pressure regulating or expansion valve 12 may be disposed. The low pressure side of the pressure regulating or expansion valve 12 is connected with a coil 13 which in turn is connected with a pressure regulating valve 14 at the high pressure side of the latter and valve 14 connects at its low pressure side with what may be termed consumer line 15 leading to a burner 16 or other place of use of the fuel vapor. A pressure released safety vent on the low pressure side of the pressure regulating valve 14 is represented by the pipe 17.

An electric motor M drives a refrigerant compressor C which discharges compressed refrigerant into the line 21 from which it may flow through condenser coil 22 or through a coil 23 to effect condensation thereof and thence through an expansion valve 24 into an evaporator coil 25 of a refrigerating box or unit and thence back to the compressor through a return line 26. If desired the fuel or some of it may be used to generate steam in a boiler B the steam being utilized in an engine 27 to drive a generator G to supply electricity to run the motor M, but other means for supplying the power to operate the compressor may be utilized as will be understood.

The fuel vapor coil 13 and the refrigerant condenser coil 23 are placed in heat exchange relation with one another, preferably within a tank 28 which may be filled with water or brine or other heat conducting medium. If desired the tank 28 may be insulated but it is considered preferable not to insulate this tank since if excess heat units from the refrigerant are supplied such excess may be dissipated through the tank walls to the atmosphere, whereas, if additional heat units are needed to heat or to super-heat the fuel vapor in the coil 13, the tank may pick up some or all of such additional heat units by conduction from the atmosphere.

The heat absorbed from the earth by the liquid fuel in the tank 2 will vaporize a part of the liquid fuel thereby to create sufficient pressure within the tank to lift the fuel either in its liquid state through the liquid line 5 or in its gaseous state through the gas line 4 to the coil 13 and the place or places of fuel consumption. The valves 6 and 7 may be operated to supply either fuel vapor or liquid fuel or a mixture to the supply line 9, as will be understood. If vapor is passing through the supply line 9, the valve 12 should be a pressure control valve whereas, if liquid is passing into line 9, the valve 12 should be an expansion valve. After the vapor has passed through the coil 13 and has been heated by the heat units supplied from the refrigerating apparatus including the latent heat of the refrigerant to effect condensation thereof, it passes to the pressure regulator 14 and thence to the consumer demand line 15.

In Fig 2 the compressed refrigerant passes into line 21*a* from the compressor, thence through condenser 22*a*, thence through condenser coil 23*a* in heat exchange relation with vapor coil 13, thence to expansion valve 24*a* and, after passing through the evaporator coil 25*a*, returns to the compressor through line 26*a*. In this system the refrigerant passes through the coils 22*a* and 23*a* in series instead of in parallel. As will be appreciated and understood, the coil 22*a* may be wholly omitted from the system shown in Fig. 2. If desired the coil 22*a* may be placed in heat exchange relation with the vapor coil 13 in which case the coil 23*a* may be used to dissipate any excess heat not taken out by the vapor in coil 13.

In Fig. 3 the liquid fuel in tank 2*a* is heated and vaporized by the waste heat from refrigerant supplied through a line 31 and is returned to the refrigerant evaporator through the line 32. The refrigerant passes through a coil 33 which may be either submerged in the liquid fuel in the tank 2*a* or disposed in thermal contact relation with the tank walls, as may be preferred. Any excess heat supplied to the liquid fuel which would cause a rise in the temperature of the liquid fuel above the temperature of the surrounding earth would be dissipated into the earth through the tank walls. The application of heat to a low point of the liquid in the tank or to a low point of the tank will cause convection currents to flow in or boiling of the liquid fuel within the supply tank or reservoir and thereby will tend to homogenize the vapors of the different liquid fuels comprising the fuel mixture within the tank. Consequently the fuel vapors passing into the fuel supply line will be uniform or substantially uniform in character, that is, will maintain substantially definite proportions of constituents until the tank contents are exhausted.

In Fig. 4, an absorption type refrigeration system is shown in combination with a liquid-to-vapor fuel supply system. An underground fuel supply tank 2*b* is connected through a vapor line 4*b* and a liquid line 5*b*, shut off valves 6*b* and 7*b*, respectively, with a supply line 9*b*. A

pressure regulating valve or expansion valve 12b is located between the line 9b and the line 34 which connects through a valve 35, line 36, coil 37, valve 38 and line 39, with a burner or consumer demand line 41, and also through a valve 42, line 43, coil 44, and line 45 with line 41. By-pass line 46 and valve 47 provide intercommunication between the coils 37 and 44 for a purpose to be described. The consumer demand or service line 41 may lead to any suitable place of use of the fuel vapors and may supply a burner 48.

The absorption type refrigeration system diagrammatically incorporated in Fig. 4 includes a generator 51 heated by the burner 48 and in which the ammonia gas is boiled from a strong or saturated water solution, the gas and a portion of the strong solution being pumped by vapor lift action upwardly through the pump tube 52 to a weak solution stand-pipe 53 where the strong ammonia gas separates and passes through line 54 to an ammonia condenser 55, the weakened solution dropping down in the stand-pipe 53 into chamber 56 for recycling. The liquified ammonia from the condenser 55 flows into cooling coils 57 and 58 the first of which may be the box cooling evaporator coil and the latter of which may be the freezing evaporator coil. After and during the time the ammonia absorbs heat it passes in contact and mixes with hydrogen gas and the commingled gases, the hydrogen and the evaporated ammonia gas, pass through the pipe 61 to an absorber. The mixture of ammonia and hydrogen gases may flow through a gas heat exchanger 62 and through line 63 into the absorber 64. An auxiliary line 65 connecting between the freezing coil 58 and the ammonia-hydrogen gas return line in the heat exchanger 62, may be provided if desired.

The mixed hydrogen and ammonia gases flow upwardly through the absorber 64 past baffles or trays 66 over which the weak ammonia water solution trickles down, the weak solution absorbing the ammonia from the hydrogen gas and becoming strong ammonia solution which is returned to the generator 51. The released hydrogen gas flows upwardly from the absorber through line 67 and the gas heat exchanger 62, returning into line 59 to repeat its cycle. The weak solution flowing from chamber 56 passes through line 68, a coil 69 in heat exchange relation with a coil 71 containing the strong solution of ammonia in water, and thence passes through line 72 to the top of the absorber 64 where it enters the absorber to pick up the ammonia gas and form a strong solution. The strong solution returns to the generator from the bottom of the absorber through a line 73, heat exchange coil 71 and line 74. Surrounding the absorber 64 is a coil 75 in heat exchange relation therewith. The coil 75 may contain methyl chloride which absorbs heat from the absorber, boils and vaporizes, the vapor flowing through line 76 into condensing coils 77 and, after condensing, returns through line 78 to the heat exchanger coil 75.

It will be noted that the coil 37 of the gas supply line is disposed in heat exchange relation with the methyl chloride condenser coil 77 thereby to extract heat from the methyl chloride, and it will also be noted that the coil 44, also in the gas supply line, is disposed in heat exchange relation with the ammonia condenser coil 55 thereby to extract heat from the ammonia gas and to condense the same. Auxiliary cooling means such as a fan may be provided for the ammonia condensing coil 55 and for the methylchloride condensing coil 77 or these coils may be cooled in any other manner should it be necessary or desirable so to do in case there is insufficient flow of gas through the gas supply line and the coils 37 and 44. If it should be desired, the methyl chloride cooling system may be omitted and a fuel vapor coil substituted therefor to absorb the heat from the absorber, or a combination of both systems may be used.

The arrangement is such that either or both of coils 37 and 44 may be used. For instance should it be desired to use the coil 37 only, the valves 42 and 47 will be closed and the valves 35 and 38 will be opened, or, if the coil 44 only, is to be used the valves 35, 38 and 47 may be closed and the valve 42 opened or, if both coils 37 and 44 are to be used the valves 42 and 38 will be closed and the valves 35 and 47 opened, all as will be appreciated. In the manner apparent from the description given both the internal heat of work done upon the refrigerant as well as the heat absorbed from within refrigerator box may be put to useful work in heating or super-heating the vapors from liquid fuel thereby to improve the combustion and other characteristics thereof. While the absorber system has been illustrated and described in connection with the heating or super-heating of vapors from liquid fuel, it may be adapted, as will be appreciated, to vaporization of the liquid fuel. Various controls including inter-related controls between the refrigeration system and the gas supply system may be incorporated and various modifications and arrangements of the apparatus per se or of the system as a whole may be provided.

While the invention has been illustrated in several forms, many other embodiments may be readily devised when the principles are understood. Consequently I desire to be limited only by the spirit of the invention as comprehended within the scope of the appended claims.

I claim:

1. In the art of operating a system in which liquid fuel contained in an underground reservoir is to be vaporized for combustion, the method of treating said fuel which comprises transferring the waste heat carried by a refrigerant from a refrigerating apparatus to said fuel in said reservoir out of actual contact with the refrigerant.

2. In the art of operating a system in which liquid fuel contained in an underground reservoir is to be vaporized for combustion, the method of treating said fuel which comprises transferring the waste heat carried by a refrigerant from a refrigerating apparatus to said fuel out of actual contact therewith and at a place below the liquid level in said reservoir, thereafter passing the heated fuel to a place of combustion, and recycling the refrigerant through said apparatus.

3. In the art of operating a system in which liquid fuel of the class including propane and butane is contained in an underground storage reservoir and is vaporized therefrom for combustion, the method of applying heat to said fuel which comprises, transferring the waste heat from the vapors of refrigerant of a closed cycle refrigerating system to said fuel thereby to heat said fuel and to cool said refrigerant, said transfer being made adjacent to the bottom of said reservoir thereby to produce convection currents in the liquid fuel in said reservoir.

4. In the art of operating a system in which

liquid fuel of the class including propane and butane and mixtures thereof is stored in an underground reservoir and in heat transfer relation with the earth and is vaporized for combustion, the method of heating the said fuel to vaporize the same which comprises, passing at least a part of the waste heat laden vapor of a refrigerant in a closed refrigerating system in heat exchange relation with a low portion of the body of the fuel within the reservoir.

5. In combination, a liquid fuel reservoir, a gas burner, means for conveying vapors from liquid fuel supplied by the reservoir to said burner, a refrigeration system including a compressor and a closed cycle for the refrigerant, and means for transferring heat to be dissipated from the refrigerant to the fuel to be conveyed to said burner.

6. In combination, a liquid-to-vapor fuel supply system including a liquid fuel reservoir, a vapor burner and a fuel supply line from said reservoir to said burner, a refrigerating system including a compressor and an evaporator, and means for transferring heat absorbed by refrigerant in the evaporator to the fuel to be conveyed to the burner through said fuel supply line.

7. In combination, a liquid-to-vapor fuel supply system including a liquid fuel reservoir, a vapor burner, and a fuel supply line from said reservoir to said burner, a refrigerating system including an evaporator, and means including a compressor and a heat exchanger in operative relation between the refrigerant system and the fuel supply system for the transfer of heat units from the refrigerating system to said fuel supply system.

8. In a combination, a liquid-to-vapor fuel supply system including a liquid fuel reservoir, a burner and a supply line connecting said burner and reservoir, a refrigerating system including a compressor, an evaporator, and a condenser, and means associating said condenser and said fuel supply line in heat transfer relation.

9. In combination, a liquid-to-vapor fuel supply system including an underground liquid fuel reservoir, a burner and a supply line connecting said burner and reservoir, a refrigerating system including a compressor, an evaporator, and a condenser, and means including a part of said refrigerating system between said compressor and said evaporator and associated with said fuel system for transferring heat units from the refrigerating system into said fuel system.

10. In combination, a liquid-to-vapor fuel supply system including a liquid fuel reservoir, a burner and a supply line connecting said burner and reservoir, a refrigerating system including a compressor, an evaporator, and a condenser, and means in series with said condenser and associated with said fuel system for transferring heat units from the refrigerating system into said fuel system.

11. In combination, a liquid-to-vapor fuel supply system including a liquid fuel reservoir, a burner and a supply line connecting said burner and reservoir, a refrigerating system including a compressor, an evaporator, and a condenser, and means in parallel with said condenser and associated with said fuel system for transferring heat units from the refrigerating system into said fuel system.

12. In combination, an underground liquid fuel reservoir, a gas burner, means for conveying vapors from liquid fuel in said reservoir to said burner, a refrigeration system including an evaporator, a compressor, and means interconnecting the evaporator and the compressor in a closed cycle for the refrigerant, the means connecting the high pressure side of said compressor with the evaporator including means disposed in heat exchange relation with the liquid fuel in said reservoir.

13. In a system in which liquid fuel of the class including propane and butane and mixtures thereof is vaporized for combustion, the combination of means for storing said fuel in a tank in heat exchange relationship with the earth, a coil in heat exchange relationship with the contents of the tank, means for withdrawing said fuel from the tank, and means for maintaining a uniformity in the fuel mixtures throughout the tank including said coil and means utilizing refrigerant waste heat for establishing a temperature differential between the coil and the contents of the tank to circulate the contents of the tank convectively.

14. In combination, a vaporizing chamber, means for holding under pressure a liquid having a boiling point below the freezing point of water, means for supplying said liquid to said vaporizing chamber at a reduced pressure, a refrigerating system comprising a closed conduit for the refrigerant including a condenser section in heat exchange relationship with said vaporizing chamber and an evaporator section in heat exchange relationship with space to be refrigerated, and a refrigerant in said conduit means for conveying heat from said refrigerating system to said chamber.

15. In combination, a vaporizer including an element defining a circuitous passageway, means for holding a fluid having a boiling point below the freezing point of water, means for creating fluid pressure in said holding means and maintaining said fluid in its liquid and vapor phases, means for supplying said fluid in its liquid phase to said vaporizer at a reduced pressure including an expansion valve, a refrigerating system comprising conduit means for the refrigerant including evaporator and condenser sections in heat exchange relationship with space to be refrigerated and said vaporizer respectively.

16. The combination of a vaporizer including means defining a circuitous passageway, means for storing a fluid having a boiling point below the freezing point of water, means for holding said fluid in both its vapor and liquid phases and establishing a fluid pressure within the storing means, means for supplying said fluid in its liquid phase to said circuitous passageway including a fluid flow control means, a refrigerating device including conduit means having a refrigerant therein in both its liquid and vapor phases, means for transferring heat from a portion of said conduit means having vapor therein to said circuitous passageway including a stabilizing element tending to assume the temperature of said vaporizer and to receive heat units from said portion of said conduit means without contacting the fluid or refrigerant.

17. In combination, means for storing fuel under pressure in its liquid and vapor phases, means for dispensing said fluid in its vapor phase including a conduit means and a pressure reducing element therein, a refrigerating system including a closed cycle for the refrigerant, means for establishing a higher pressure in one part of the closed cycle including a pressure reducing device, and means for transferring heat from the refrigerant upon the high pressure side of said pres-

sure reducing device to the conduit means upon the low pressure side of said pressure reducing element.

18. In combination, a liquid-to-vapor fuel supply system including a liquid fuel reservoir, a burner, and a supply line connecting said burner and reservoir, a refrigerating system including means for dissipating heat units from the spent refrigerant, means for transferring heat units from said dissipating means to the fuel supplied to said burner, and means driven by the heat of said burner to move the refrigerant in said refrigerating system.

19. In a liquid-to-gas fuel system employing liquid fuel of the character of propane and butane, the combination comprising a source of heat, a supply tank of liquid fuel, a fuel conduit extending from a point adjacent the bottom of said supply tank for delivering fuel therefrom, means in said conduit for reducing the pressure on liquid fuel therein, a vaporizer comprising a tank having a portion of said fuel conduit downstream of said means in heat exchange relationship with the tank contents for vaporizing the fuel in said conduit portion, means for conducting a heat exchange medium from said heat source, said means including one branch arranged for supplying heat to said tank contents and to the fuel at reduced pressure in said conduit portion and including also a second branch arranged for bypassing said tank contents and the fuel in said conduit portion and for dissipating heat from said medium, and means for delivering the vaporized fuel to a point of use from said conduit portion.

20. In a liquid-to-gas fuel system employing liquid fuel of the character of propane and butane, the combination comprising a source of hot refrigerant, a supply tank of liquid fuel, a fuel conduit extending from a point adjacent the bottom of said supply tank for delivering fuel therefrom, means in said fuel conduit for reducing the pressure on liquid fuel therein, a vaporizer comprising a tank having a portion of said fuel conduit downstream of said means in heat exchange relationship with the tank contents for vaporizing the fuel in said conduit portion, means for conducting refrigerant from said source including one branch traversing the vaporizer tank for supplying heat to said tank contents and to the fuel at reduced pressure in said conduit portion and including also a second branch arranged for bypassing said tank contents and the fuel in said conduit portion and for dissipating heat from said refrigerant, means for delivering the vaporized fuel to a point of use from said conduit portion, and means for returning cooled refrigerant from said branches to said source.

OLAF R. ANDERSON.

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Certificate of Correction

Patent No. 2,418,446. April 8, 1947.

OLAF R. ANDERSON

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows: Column 6, line 59, claim 2, strike out "therewith" and insert instead *with the refrigerant*; column 7, lines 31 and 32, claim 7, strike out "a compressor and" and insert the same in line 31, same claim, after "including", first occurrence; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 29th day of July, A. D. 1947.

[SEAL]

LESLIE FRAZER,
First Assistant Commissioner of Patents.