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1,905,971

PROCESS AND APPARATUS FOR REFRIGERATION WITH LIQUEFIED FUEL GAS

Filed July 28, 1931

2 Sheets-Sheet 1

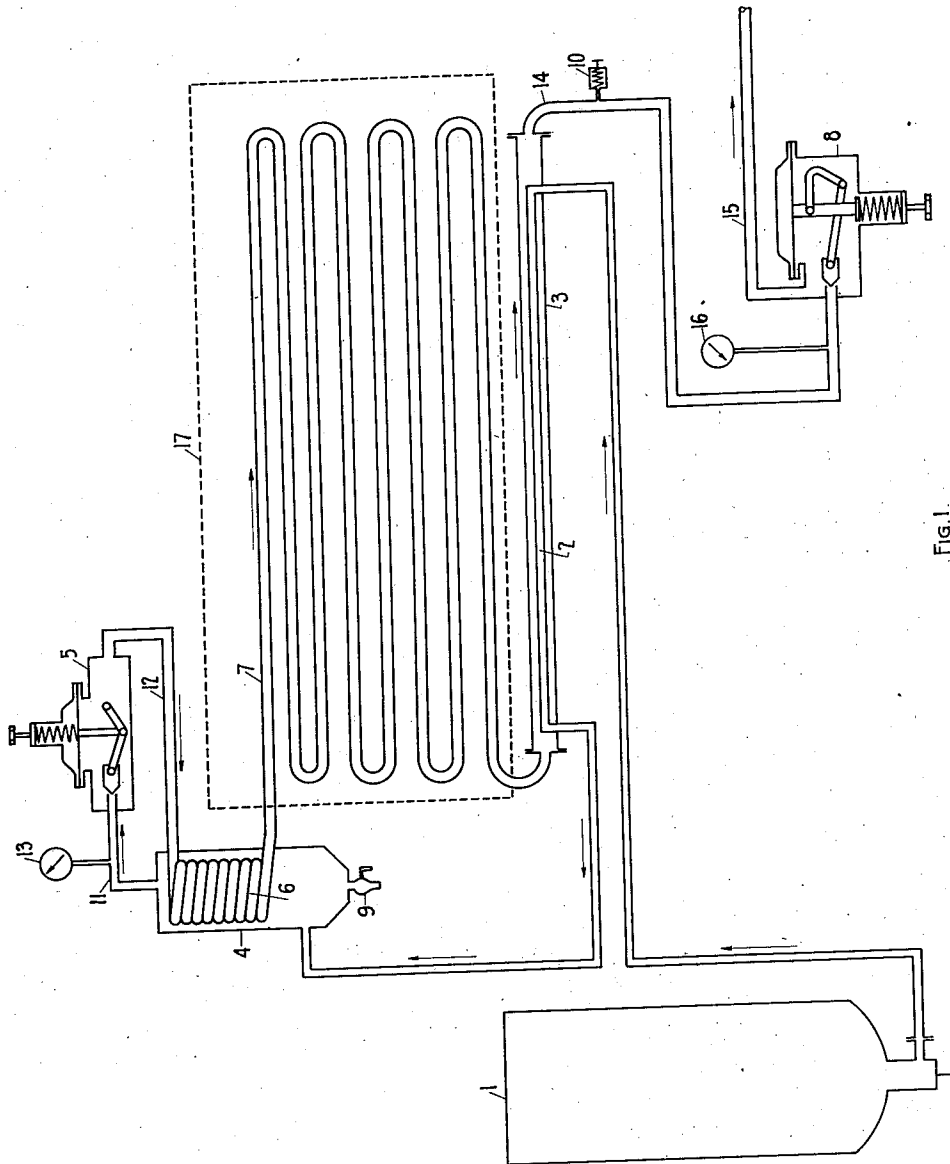


FIG. 1.

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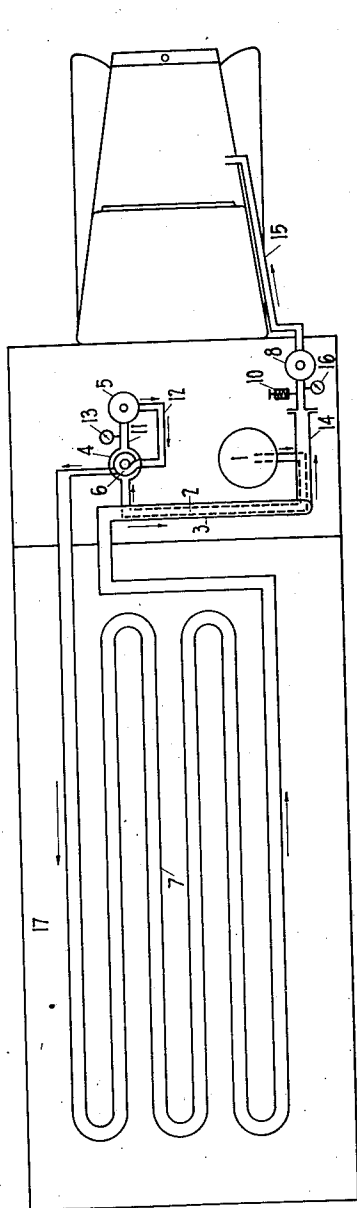


FIG. 2

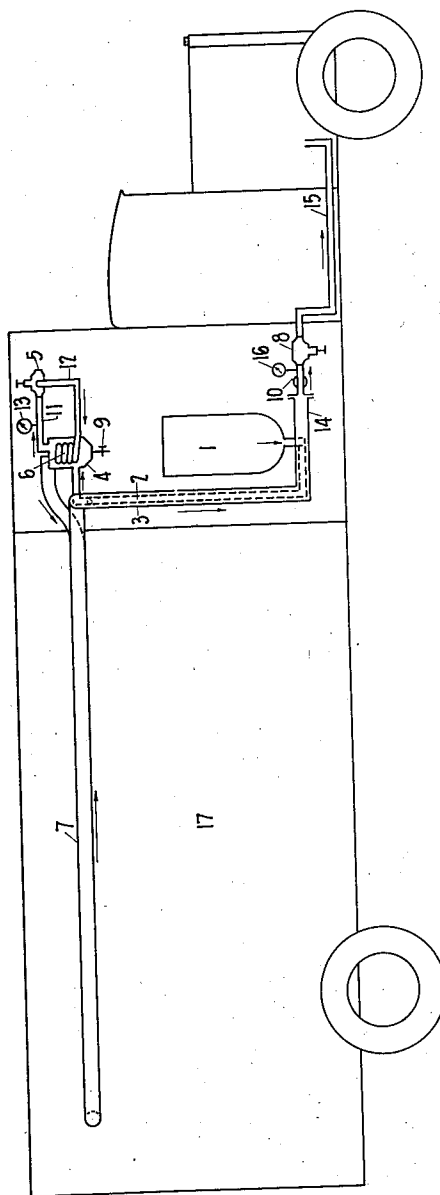


FIG. 3

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UNITED STATES PATENT OFFICE

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PROCESS AND APPARATUS FOR REFRIGERATION WITH LIQUEFIED FUEL GAS

Application filed July 28, 1931. Serial No. 553,524.

This invention relates to a dual system wherein a direct expansion type cooling and refrigerating system is operated in conjunction with a fuel gas consuming unit, and is more particularly concerned with a process wherein the cooling refrigerating medium is combusted with a gas, after it has passed through the refrigerating system.

The objects and advantages of this improvement will be so clearly apparent to those skilled in the industry, as incidental to the following disclosure, that it would serve no useful purpose to further enlarge upon the same initially. With these prefacing remarks, therefore, reference now will be immediately had to the accompanying drawings, generally illustrating at least one practical embodiment of a novel systematic combination of means for carrying forth the steps of the method involved, although not essentially the only apparatus for doing so. Of these drawings:

Fig. 1 illustrates a general flow diagram of the disclosed arrangement of the refrigerating system.

Figs. 2 and 3 are plan and side elevation views, respectively, of the improved refrigerating system installed on a truck.

In the drawings, wherein like characters of reference designate corresponding parts throughout the several views, storage tank 1 is in communication with a heat exchanger 4 by means of conduit 2. Portion 3 of a set of expansion coils 7 is arranged in heat exchange relationship with conduit 2, and the other portion 6 of coils 7, externally located of the cooling or refrigerating compartment 17 is arranged in 4, constituting part of the said heat exchanger. Pipes 11 and 12 bring the fluid surrounding the outside of coils 6 in the heat exchanger 4 into coils 6 in the general direction of flow, as indicated on the drawings. A high pressure regulator 5 is interposed between lines 11 and 12 and serves to maintain a predetermined pressure on the system at a particular operating temperature. A pressure gauge 13 may be stationed before 5 and communicate with line 11 so as to indicate the prevailing pressure in the system up to that point. Expansion coils 7 are located in a refrigerating compartment 17 suitably mounted on any convenient support or vehicle and are adapted to bring about the lowering of the temperature therein. The exit line 14 of cooling coils 7 leads to a combustion or power device not specifically disclosed. A low pressure regulator 8 is interposed in line 14 and operates to open the line when the pressure in line 15 falls to a predetermined value, which is lower than the pressure in line 14 and may be less than atmospheric. A suitable pressure gauge 16 may be located in line 14. If desired, a pressure relief valve 10 may be adjusted in line 14 so as to reduce or minimize the pressure existing therein, if it rises above a predetermined point.

Preparatory to starting operations, the liquefied, normally gaseous fuel is stored in the high pressure section of the system, i. e., in storage tank 1, line 2, the jacket of heat exchanger 4 and line 11 extending to the high pressure regulator 5. The fuel under a pressure, and at the temperature at which it is maintained in the liquid state, flows through 2 in heat exchange relationship with the expanded exit fluid from expansion coils 7 in the last section, 3 thereof, which is positioned externally of the refrigerating compartment 17, as in Figs. 2 and 3, although, if desired, section 3 and line 2 may be positioned inside of refrigerating compartment 17, thus constituting a part of cooling coils 7. The liquid fuel flows from 2 in a cooled state to heat exchanger 4, where it is further cooled, and passes by means of line 11 through high pressure regulator 5 where the pressure in the system is stepped down to a predetermined one, normally one about a few pounds above atmospheric pressure. The fuel is still a liquid at this reduced pressure due to the corresponding lowering of its temperature by means of the heat exchangers.

Heat exchanger 4 serves to remove water which may be present in the system, as the water will solidify or freeze on the outside of coil 6 in heat exchanger 4 due to the low temperature prevailing therein, and can subsequently be readily removed by stopping the

flow momentarily and defrosting in the usual manner, using drain valve 9 to remove water from the system.

The cooled fluid flowing through 12 and 6 takes up heat in the heat exchanger 4 and is vaporized in the expansion coils 7 located in the cooling or refrigerating compartment 17, contained in the desired structure. The liquid in vaporizing in coils 7 takes up heat equivalent to its latent heat of vaporization, consequently lowering the temperature prevailing in the refrigeration compartment and cooling the same in proportion. As the cold gas passes out of the refrigerating coils 7 it is utilized to cool the liquid entering at relatively high temperature and pressure into the system. The exit gas in 14 is controlled by low pressure regulator 8 which is adapted to permit flow of the same to a combustion or power device, when the pressure in line 15 becomes lower than a predetermined one. Were low pressure regulator 8 not to operate, or a pressure tend to build up in line 14, pressure relief valve 10 serves to vent such increased pressure to the atmosphere, or to any desired apparatus; for example, it may also communicate with the same or different combustion or power devices.

For illustrative purposes only, reference will be had to the execution of our process with a preferred fuel, although it is to be understood that our invention is not to be restricted thereto, as it is capable of use with substantially any liquefied normally gaseous fuel or mixtures of the same, particularly with hydrocarbon fuel.

A refrigerating system of the type described hereto, using liquefied butane as refrigerant, is installed on a truck, the motor of said truck being operated by combusting the exit gaseous butane from aforesaid system.

The storage tank 1 containing liquefied butane at 75° F. under a relative pressure of about 125 lbs./sq. in. is properly connected to the system and its stop valve opened. If the relative pressure in coils 6 and 7 were less than 2 lbs./sq. in. gauge, the regulator 5 will admit some of the compressed butane into these coils, until 2 lbs./sq. in. pressure is reached, when flow is automatically cut off. The low pressure regulator 8 remains closed until suction is produced by the motor in line 15. Starting the motor by reciprocating pistons within its cylinders causes partial vacuum in the intake manifold, which is communicated through a throttling device and line 15 to the regulator 8. As soon as the subatmospheric pressure reaches the predetermined value of 10 lbs./sq. in. absolute in line 15, the regulator 8 opens and releases pressure in coils 7 and 6, which in turn causes regulator 5 to open and release some of the liquid butane into coils 6. The released fluid rapidly evaporates in coils 6 as result of

change in pressure from 125 lbs./sq. in. to about 2 lbs./sq. in. and absorbs heat from the liquid butane flowing in the jacket of heat exchanger 4, lowering its temperature. The rate of evaporation of butane within coils 6 gradually decreases due to the cooling of the liquid butane in heat exchanger 4; finally a substantial portion of liquid begins to pass into coils 7 where it is completely vaporized with the corresponding lowering of temperature in cooling compartment 17. Passing further through a heat exchanger 3 the gas is heated to a temperature of about 50-55° F.

When the motor is running steady for a period of time, a continuous and more or less uniform flow of butane is maintained throughout the system, and general equilibrium conditions therein ensue. In this particular illustrative case, the pressure of 2 lbs./sq. in. gauge in expansion coils 7 determines the temperature of the fluid in coils 6 as about 15° F. which is the vaporization temperature of butane under 2 lbs./sq. in. gauge pressure. As the result of taking up the heat in coils 7, the temperature of the gas reaching heat exchanger 3 is raised to about 20-25° F., and thereafter to about 50-55° F., whereas the temperature of the liquid butane in coil 2 is lowered from about 75° F. to about 35-40° F. and to about 20° F. after additional cooling in heat exchanger 4. It is noted that the temperatures in heat exchanger 4 are sufficiently below the freezing point of water to effect its complete removal by the solidification of the same on the outside surface of coils 6; thus danger of freezing the regulator 5 is eliminated. It is also noted that the gaseous butane used as motor fuel is conveniently preheated to an elevated temperature—which is a very advantageous feature of this system.

The rate of fuel flow to the motor is controlled by a special throttling device not subject to this specification.

The conditions after the motor has been stopped are substantially as follows: both regulators, 5 and 8, close immediately after pressures on the downstream side of each have risen to those originally predetermined, namely, 2 lbs./sq. in. gauge pressure and 10 lbs./sq. in. absolute, respectively. As the closed section of the system between regulators 5 and 8 contains some liquid butane in coils 6, the pressure within this section will rise until all of the liquid is evaporated, and the temperature of the surroundings is reached. This ultimate pressure, if tending to be excessively high, is controlled by the relief valve 10, which could be set, for instance, for 40 lb./sq. in. gauge. This limiting pressure may never be reached, however, as the amount of liquid butane in coils 6 is comparatively small and therefore insufficient to produce gas generating such a pressure in coils 7.

Conditions somewhat different in details, but similar in general effect, can be attained by the use of other hydrocarbons, such as either iso-butane, or butylenes, or propane, or propylene, etc., or mixtures thereof. The presence of lighter or heavier hydrocarbons in the mixture is undesirable under ordinary conditions; the presence of even small percent of ethane, for instance, would require excessively high pressures within sections of the system containing the liquefied gas, while if pentane be present the boiling temperature in coils 6 and 7 would not be sufficiently low to effect satisfactory refrigeration, although cooling effects could be produced. Besides hydrocarbons, their substitution products, or any other combustible gases, which could be liquefied within reasonable economic limits of pressure and the boiling point of which at atmospheric pressure is not substantially above 40° F., and preferably below, can be used in a practical application of this invention.

While the foregoing is only a general description of the main pieces of equipment necessary to carry out the operation of the system in its simplest form, in actual practice additional parts may be utilized such as thermometers, valves, etc., or a different arrangement of cooling coils may be used as in the case of utilizing the produced refrigerating effect for the purpose of cooling the motor by means of another heat transmitting medium, such as water or oil. Various modifications may be deemed advisable for specific uses of the described refrigerating system; these uses may include, besides installations on various types of trucks, passenger busses or vehicles, where cooling and not refrigeration is desired, installations on boats, stationary units, in dining cars, in country homes and other structures where combustible gas may be used for cooking, illuminating or power-producing purposes, or, generally, whenever the low cost of construction and maintenance of a refrigerating unit, ruggedness and compactness of apparatus, and available use for a gaseous fuel are determining factors.

It will be obvious, therefore, that various substitutions in the combustible and/or refrigerating material, as well as, modifications in the arrangement of different members of the system may be made in the practical application of this invention, but such substitutions and modifications are to be considered as comprehended by the above disclosure and included within purview of the following claims.

We claim as our invention:

1. A fuel utilizing system comprising: a storage vessel for fuel, an expansion unit supported in a refrigeration compartment, one end of said unit being in communication with a storage vessel, a high pressure regulator interposed between said vessel and said expansion unit, a combustion device in communication with the other end of the expansion unit and a low pressure regulator interposed between said expansion unit and the combustion device whereby said expansion unit is maintained under super-atmospheric pressure.
2. Process of refrigerating comprising reducing the pressure on a normally gaseous fuel stored under high pressure, vaporizing said fuel under super-atmospheric pressure, reducing the pressure on the gas produced and thereafter combusting all of said gas.
3. Process of refrigerating comprising reducing the pressure on a propane butane mixture stored under high pressure, vaporizing said mixture under super-atmospheric pressure, reducing the pressure on the gas produced and thereafter combusting all of said gas.
4. Process of operating a refrigerating motor truck comprising reducing the pressure on a liquefied hydrocarbon gas stored under high pressure, vaporizing said liquefied hydrocarbon gas under super-atmospheric pressure, reducing the pressure on the gas produced, thereafter operating the internal combustion motor of said truck by said gas.
5. Method of refrigerating a motor truck comprising: expanding and vaporizing a normally gaseous refrigerant suitable as motor fuel in a refrigerating coil while maintaining said coil under super-atmospheric pressure, withdrawing the gas evolved in said coil and thereafter passing said gas into the motor of said truck.
6. Process of operating a refrigerating motor truck comprising: reducing the pressure on a propane-butane mixture stored under high pressure, vaporizing said mixture under super-atmospheric pressure, reducing the pressure on the gas produced, thereafter operating the internal combustion motor of said truck by said gas.
7. Process of operating a refrigerating motor truck comprising: reducing the pressure on a propane-butane mixture stored under high pressure, vaporizing said mixture under super-atmospheric pressure, reducing the pressure on the gas produced, thereafter operating the internal combustion motor of said truck solely by means of said gas.
8. Process of operating a refrigerating motor truck comprising: reducing the pressure on a liquefied hydrocarbon gas to about two pounds per square inch, evaporating said hydrocarbon in a coil under a pressure of about two pounds per square inch, then passing the gas produced into the motor of said truck.
9. Process of operating a refrigerating motor truck comprising: reducing the pressure on a liquefied hydrocarbon gas from about one hundred and twenty five pounds per

square inch to about two pounds per square inch, evaporating said hydrocarbon in a coil under a pressure of about two pounds per square inch, then passing the gas produced
5 into the motor of said truck.

10. A refrigerating motor truck operated by liquefied gas comprising: a high pressure liquefied gas container, a line connecting said container with the motor of said truck, a re-
10 frigerating coil in said line and a pressure regulator connected to said coil.

11. A refrigerating motor truck operated by liquefied gas comprising: a high pressure liquefied gas container, a line connecting said
15 container with a pressure regulator, a refrigerating coil attached to said regulator, and a line from said refrigerating coil to the motor of said truck.

12. A refrigerating motor truck operated
20 by liquefied gas comprising: a high pressure liquefied gas container, a line connecting said container with a pressure regulator, a refrigerating coil attached to said pressure regulator, a line from said refrigerating coil to
25 the motor of said truck, and a second pressure regulator in said line to the motor.

In testimony whereof, we have hereunto set our hands.

30 DELOS W. DAVISSON.
FERDINAND G. WELKE.

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