

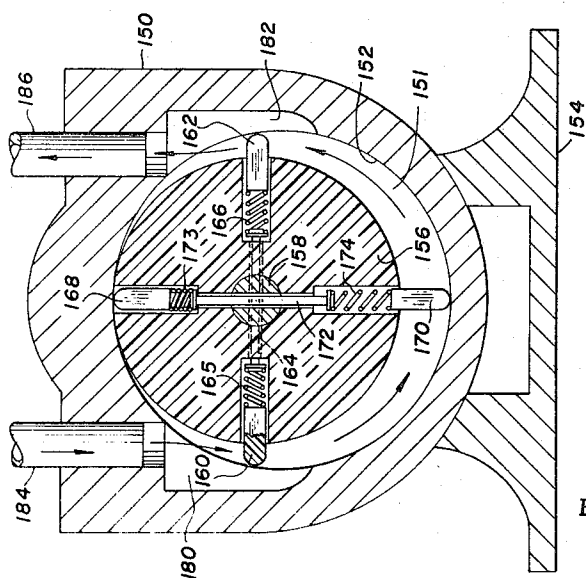
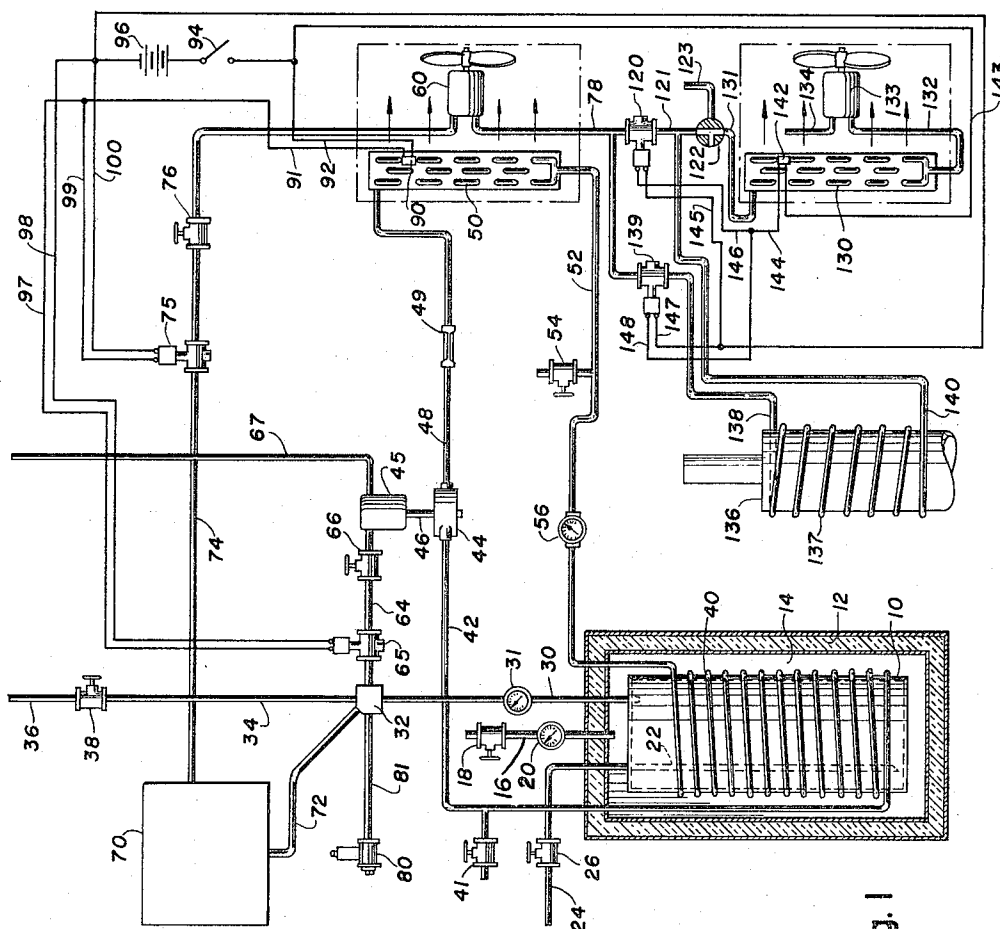
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LIQUID GAS REFRIGERATION SYSTEM

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LIQUID GAS REFRIGERATION SYSTEM

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ABSTRACT OF THE DISCLOSURE

This invention relates to a refrigeration system utilizing a liquid gas as a cold reservoir and a vaporizable refrigerant that is circulated through a vaporizer and a condenser, the latter being situated in heat exchange relation with said liquid gas reservoir to condense the refrigerant. The vapor from the liquid gas is used to drive pump means for circulating the refrigerant through the vaporizer and condenser.

There are basically two types of refrigeration systems which are of commercial significance. One of these systems uses a refrigerant and a compressor for condensing or liquifying the refrigerant, so that upon vaporization, the refrigerant cools its environment. The other system uses natural gas and the principle of the heat pump, wherein a refrigerant is successively condensed, vaporized and recondensed. The first system is expensive in both its cost and upkeep, primarily because of the compressor required. The second system, although requiring no compressor, is quite costly to purchase. Both of these systems are relatively complex in the number of parts used, in addition to which, both systems require an external source of energy for operation. In the system using a compressor, a source of electrical energy is required, and in the other system, a source of natural gas is required.

Systems utilizing a low temperature substance for a cold reservoir have also been devised, although none of these systems have met with commercial success. However, the desirability of such a system utilizing a low temperature substance as a cold reservoir will be appreciated, since this basically eliminates the requirement for a compressor or a source of natural gas. The lack of success of previous systems has been due to several factors, including the lack of availability of suitable substances which will provide an efficient cold reservoir. The predominant reason for the inadequacy of such systems, however, has been the improper utilization of the cold reservoir to obtain maximum efficiency in conjunction with the required cooling effect.

The broad object of the invention is to provide a refrigeration system using a contained liquid gas as a low temperature or cold reservoir and a refrigerant which is cooled thereby for refrigerating a volume, whereby maximum utilization of the liquid gas is achieved to provide a system having a maximum cooling ability and efficiency. To effect this, the preferred embodiment of the invention uses liquid nitrogen as a cold reservoir and a vaporizable refrigerant that is cooled and condensed thereby, whereby the refrigerant is circulated in a fluid circuit through a set of cooling coils and vaporized therein by a flow of air which is forced across the coils to cool any desired volume. Since a quantity of liquid gas, when contained, will develop a considerable vapor pressure, this vapor pressure is used to perform useful work in the system in addition to its cooling function, and in particular, is used to drive both a gas driven pumping means for circulating the refrigerant and gas driven ventilating means for forcing a flow of air across cooling coils.

Many other objects, features and advantages of present invention will become readily apparent from the following detailed description when taken in conjunction

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with the appended claims and the attached drawing, wherein:

FIGURE 1 is a schematic diagram of a preferred embodiment of the refrigeration system of the invention; and

FIGURE 2 is an elevational view in section of an air driven motor adapted for being operated from a source of vaporized liquid gas to provide power means for operation of the system.

Referring now to FIGURE 1, a container 10 for containing a quantity of a liquid gas is disposed within a thermally insulated outer container 12, and separated from the outer container by a vacuum space 14 to provide further thermal insulation. The outer container can be comprised of any suitable heat insulating material, such as perlite aggregate, for example, having an ASTM specification of C-35-57T. A pipe 16 communicates with the vacuum space between the two containers through which a vacuum can be created, whereby a hand valve 18 can be connected at its outlet to any suitable vacuum pump (not shown) and opened and shut as desired. A vacuum gauge 20 is connected within pipe 16 to monitor the vacuum about container 10.

A pipe 22, shown in phantom, is sealed through both the outer and inner containers by vacuum seals and communicates at its open end with the bottom of container 10 for filling the container with a liquid gas. The liquid gas is passed into container 10 from a source (not shown) connected to inlet pipe 24 connected to pipe 22 through a hand valve 26.

A conduit 30, also sealed through both containers, communicates with the upper interior of container 10 and is connected at its other end to a conduit junction 32 through a pressure gauge 31. Also connected to junction 32 is another conduit 34 which is connected at its other end to open exhaust pipe 36 through a hand valve 38.

Container 10 is filled with a liquid gas after a suitable vacuum has been established between the inner and outer containers. To fill container 10, hand valve 38 is opened to provide an exhaust for the upper interior of tank 10, and hand valve 26 is opened to admit the liquid gas from a suitable source. The exhaust is provided to eliminate a build up of vapor pressure and to allow a more complete filling of the tank. After the tank is filled, both hand valves 26 and 38 are closed.

A fluid circuit for containing a refrigerant and through which the refrigerant can be circulated is provided and includes a vaporizer section and a condenser section. The condenser section of the fluid circuit comprises a conduit 40 wound about the container 10 in physical and thermal contact therewith which, in the embodiment shown, comprises a set of condenser coils. The condenser section is connected at its lower end to a conduit 42, and conduit 42 is connected to another conduit 48 through a refrigerant pump 44. Conduit 48 includes a sight glass 49 for viewing the refrigerant within the circuit to determine if a sufficient quantity is available. Conduit 48 is then connected to the vaporizer section 50, the latter of which comprises a set of cooling coils across which a flow of air can be forced to cool any desired volume. The bottom of the cooling coils or vaporizer is connected back to the top end of the condenser section 40 by another conduit 52 through a pressure gauge 56. Pump 44 is driven by a gas driven motor 45 through a shaft 46, wherein the motor and its operation will be described below.

A vaporizable refrigerant, or refrigerant which is liquified when reduced in temperature but which vaporizes when heated, is introduced within the fluid circuit through a hand valve 41 which communicates with conduit 42. During the filling process a hand valve 54, which communicates with conduit 52, is opened to the atmosphere

so that vapor from the refrigerant can escape from the fluid circuit so as to enable the complete filling of the fluid circuit. Thereafter, both hand valves 54 and 41 are closed. Actually, hand valves 41 and 54 are sealed to prevent leakage of the refrigerant as in other air conditioners. Therefore, these joints have been shown schematically as hand valves for simplicity.

The refrigerant is circulated by pump 44 from the bottom of the condenser section 40 through the vaporizer section 50 and back to the top of the condenser section. The refrigerant is converted to the liquid form as it passes through the condenser section and is still in the liquid form as it passes through pump 44. The refrigerant is vaporized or converted to a gas as it passes through the vaporizer section due to the exchange of heat thereto from the surrounding air. Effective cooling of the surrounding air is provided by a ventilating means 60 which forces a flow of air across the vaporizer 50.

The preferred liquid gas for being used with the system of the invention is nitrogen because of its ready availability at low cost, is low temperature when reduced to the liquid form and its large vapor to liquid volume ratio. Because of the large volume expansion of the liquid nitrogen as it is converted to a gas, it will be apparent that a considerable vapor pressure will develop within the reservoir tank 10 which, if utilized, can provide a considerable source of power for operating the system and thus increasing the efficiency thereof. It will be remarked that this vapor is also at a very low temperature and could be used for cooling purposes to further increase the cooling capacity of the system. However, it has been found that the conduction of heat from the refrigerant to the container 10 is quite efficient in producing all of the desired cooling.

The preferred refrigerant for use in the fluid circuit is Freon, a trade name of the Du Pont Company. In particular, Freon 22 is preferred which, in chemical terms, is monochlorodifluoromethane. This particular Freon can be reduced to the temperature range of liquid nitrogen without freezing and is thus an ideal refrigerant for use in the system. Indeed any Freon refrigerant can be used, in addition to other refrigerants, which makes the system quite useful in its application to automobile air conditioning, wherein Freon is readily available at most, if not all, service stations.

Vapor pressure from tank 10 is used to operate pump motor 45 and a ventilating means 60 for forcing a flow of air across the vaporizer coils 50. To effect this, a conduit 64 is connected in communication with junction 32 and to the gas driven pump motor 45 through solenoid valve 65 and hand valve 66. An exhaust pipe 67 is connected to the outlet of the motor for exhausting of the vapor passing therethrough. Thus the vapor derived from the liquid gas within tank 10 is fed to the pump motor under pressure for driving the latter.

The ventilating means 60 also comprises an air or gas driven motor having a fan and is also driven from the vapor pressure established within tank 10. To effect this, a gas storage tank 70 is connected in communication with junction 32 through conduit 72, and a conduit 74 connects the gas storage tank with the input to the ventilating means 60 through a solenoid valve 75 and a hand valve 76. Thus vapor from tank 10 can also pass through junction 32 into the storage tank and eventually through ventilating means 60. The gas storage tank plays a very important role in the operation of the overall system in that very considerable pressure is established within the liquid gas tank 10 as the liquid gas is converted to the vapor form. To provide completely controllable refrigeration, it will be necessary to stop the operation of the pump motor and the ventilating means 60 from time to time. Consequently, the vapor from the liquid gas reservoir tank will not be utilized during these times, and unless storage means is provided for the vapor, this vapor must be discharged to the atmosphere to prevent an excessive

pressure build up within the liquid gas tank. Thus it will be apparent that the gas storage tank 70 acts as an equalizer to relieve the pressure from the liquid gas tank for later utilization. The gas storage tank also acts to relieve the pressure from the liquid gas tank even when the refrigerant pump and ventilating means are operating. In other words, the pressure within the liquid gas tank can build at a greater rate under some circumstances than the refrigerant pump and ventilating means can utilize the vapor therefrom. Thus the gas storage tank also acts to relieve the pressure from the liquid gas tank and to maintain the proper pressure applied to the refrigerant pump and the ventilating means. To eliminate any possibility of a dangerously excessive pressure build up within the system, a safety, pop-off valve 80 is provided in the system by connection to junction 32 by a conduit 81. This valve can be preset to open the system to the atmosphere should the pressure exceed a predetermined maximum.

The system, shown in FIGURE 1, is also automatically controlled through a temperature monitoring means comprising a thermostat 90 situated within the vaporizer coils 50 and electrically connected at one terminal 92 to one side of a battery 96 through a main switch 94. In this instance, solenoid valves 65 and 75 are thermostatically controlled, or controlled by a voltage as established thereacross to open and shut accordingly. These solenoid valves control the operation of the refrigerant pump and ventilating means, respectively, and are shut when the temperature of the surrounding volume to be cooled or refrigerated has decreased below a predetermined minimum. To effect this control, one terminal 97 of solenoid valve 65 is connected to the other terminal 91 of thermostat 90, and one terminal 99 of solenoid valve 75 is also connected to the same terminal 91 of the thermostat. The other terminals 98 and 100 of solenoid valves 65 and 75, respectively, are connected to the other side of the voltage source 96, with the first terminal of the battery being connected to the other side of main switch 94. Switch 94 is closed when it is desired to place the system into operation, whereby solenoid valve 65 and 75 are closed when the temperature of the vaporizer coils 50 drops below a predetermined minimum. Thus solenoid valves 65 and 75 can be made normally open, but it will be apparent that these valves can be made normally closed, in which case thermostat 90 will maintain a closed circuit until the temperature of the vaporizer coils rises above a predetermined maximum. During operation, the refrigerant will be circulated within the fluid circuit by pump 44 and air will be forced across the vaporizer coils 50 by ventilating means 60 until the volume to be refrigerated has been reduced to the desired temperature. At this time, solenoid valves 65 and 75 are closed in response to the thermostat to preclude further cooling until the temperature has risen by a prescribed amount. It will be remarked that solenoid valve 65 can be eliminated, or never closed, as desired while only the ventilating means is shut down, thus allowing the refrigerant to be continually circulated. This will also provide the control needed for refrigeration. Moreover, the ventilating fan can be allowed to run continuously while controllably shutting off the refrigerant pump.

The system just described is adaptable for use in all automobiles, refrigerated trucks and is useful for refrigeration of any volume. For use in an automobile, the compressor is eliminated and the cold liquid gas reservoir is used. Both the cold reservoir and vapor storage tank are quite compatible in size for this use. Moreover, the cost of liquid nitrogen, which is about four cents (4¢) per pound, makes the system quite attractive economically for all refrigeration uses, wherein the total cost of the system is much less than the cost of gas heat pump and compressor type systems. For cooling the interior of an automobile, the rate of depletion of the liquid gas is only

a fraction of a pound per hour with all of the cooling power that is possibly needed.

This system is also equally adaptable for other refrigeration applications, such as needed in refrigerated vans of trucks. If it is applied as such, the system can also be used to air condition or heat the driver cab of the truck at the same time the van is refrigerated. To effect this, another set of cooling coils 130 is provided across which a flow of air is forced by a ventilator 133 within the cab of the truck. To provide the cooling for the coils 130, a conduit 131 is connected to an exhaust conduit 78 of ventilating means 60 through a three-way valve 122, another conduit 121 and a solenoid valve 120. Valve 122, when turned as shown, connects conduits 121 and 131, but when turned 90° from that shown connects conduit 121 with an atmosphere exhaust pipe 123 and shuts off conduit 131. The latter valve position is used when no heating or air conditioning to the cab is desired. A pipe 132 connects the outlet of coils 130 to a ventilator 133 for operation, the latter also being a gas driven motor and fan combination. The vapor is then discharged to the atmosphere through pipe 134.

For purposes of heating, a conduit 138 connects a set of heating coils 137 wound about the truck muffler or other exhaust means 136 in communication with the exhaust conduit 78 from ventilator 60 through another solenoid valve 139. The other side of the heating coils is connected in communication with conduit 121 preceding cooling coils 130 by means of conduit 140. Solenoid valves 139 and 120 are normally closed and open, respectively, although the reverse can also be used, whereby both solenoids are also operated in response to a thermostat 142 positioned within coils 130 in heat conduction relation therewith. To provide this control, one thermostat terminal 144 is connected to one terminal each of solenoid valves 120 and 139 through electrical connections 146 and 148, respectively, and the other thermostat terminal 143 is connected to one side of battery 96. The other terminals 145 and 147 of solenoid valves 120 and 139 are connected to the other side of the battery.

When thermostat 142 registers above a predetermined maximum temperature, solenoid valve 139 is closed, and valve 120 is open, thus allowing the cold vapor passing through ventilator 60 to pass directly into coils 130. If the temperature registered by thermostat 142 falls below a predetermined minimum, valve 120 will be closed and valve 139 opened, thus directing the vapor passing through ventilator 60 through the heating coils 137 before it passes through coils 130. It will be apparent that cold vapor passing through coils 130 will be at a higher temperature than when the vapor initially leaves the reservoir tank. However, this is not undesirable since it is not desired to refrigerate the cab of the truck to the degree that it could be if the vapor is colder. Even so, the vapor temperature is more than adequately low to provide all the cab refrigeration required. In so far as the heating of the cab is concerned, it will be apparent that the vapor from the storage tank 70 provides a readily available medium for transferring heat from the exhaust means 136 to coils 130. Without this vapor supply, an air intake system, or water system, would be required.

An elevational view in section of an air driven motor adapted for use with the system as the ventilating means is shown in FIGURE 2. It will be remarked that a conventional air driven motor cannot be used with this system because of the low temperature of the vapor that is used to drive it, although suitable modifications can be made to adapt it for this use. The motor comprises a housing 150 which defines a central, cylindrical cavity 151 having a cylindrical wall surface 152. The housing is mounted on a base 154 for mounting the motor. A cylindrical rotor 156 is provided which is mounted eccentric of the central axis of the housing on an axle 158 mounted at either end in conventional bearings (not shown). A set of vanes 160, 162, 168 and 170 are provided within

the rotor, which vanes are elongated and substantially coextensive with the length of the rotor along the axis thereof and mounted within suitable channels. Vanes 160 and 162 are each spring-biased outwardly by springs 165 and 166, respectively, which springs bear against the inner ends of the vanes and bear against the opposite ends of a pusher rod 164 at the other ends. The pusher rod is free to move along the line connecting the two vanes as required by the pressure exerted by the springs. The outer ends of the vanes are curved to provide a smooth interface with the inner surface 152 of the motor housing. Vanes 168 and 170 are similarly mounted on the opposite ends of another pusher rod 172 through springs 173 and 174, respectively, wherein this pusher rod is also free to move along the line connecting the two vanes as determined by the spring pressures. The pusher rods 164 and 172 are non-intersecting for obvious reasons.

A first channel or cavity 180 is provided in the motor housing at one side of the rotor and communicates with a pipe or conduit 184, so that air or other gas may be supplied through the pipe to the intake 180 of the motor. Similarly, another channel or cavity 182 is provided at the other side of the rotor and communicates with another pipe 186. This motor, as appears from the drawing, can be driven in either direction with pipe 184 being used as the input and pipe 86 used as the output, or vice versa. Assuming that air under pressure is applied through pipe 184, the air pushes against the vanes to cause the rotor to turn in a counter-clockwise direction as viewed in FIGURE 2. The rotor is mounted eccentric to the axis of the motor housing so that a pressure differential or build up will be created as the rotor rotates to compress the air on the right side of the rotor when turning in a counter-clockwise direction. Thus the reason for the spring-biased air vanes to conform to the different distances between the rotor and the motor housing as the rotor rotates.

In a conventional air driven motor, the rotor and vanes are normally comprised of dissimilar metals. Use of a vapor from a liquid gas to drive the rotor of a conventional motor of this type could cause the vanes to freeze within the slots of the rotor. This would occur primarily because of the fact that the metals comprising the rotor and the vanes are dissimilar, and consequently have different thermal coefficients of expansion and contraction. Even if the rotor and vanes are comprised of the same metal, the tolerances that would have to be maintained would be too severe because of the relatively large thermal coefficients of expansion of most metals. To eliminate this problem, the rotor and vanes are manufactured of the same material which has a very low coefficient of thermal expansion and contraction. In the preferred embodiment, both the rotor and vanes are comprised of Teflon, which is commonly known and is a trade name of the Du Pont Company. This material, in addition to having a low thermal coefficient of expansion and contraction, is well adapted for the use to which it is applied in the rotor. Consequently, the motor cannot freeze up even at the low temperatures involved.

Many modifications and substitutions of the invention will undoubtedly become apparent when taken in conjunction with the preceding description thereof. However, it is intended that all such modifications and substitutions that fall within the true scope of the invention be included therein, and that the invention be limited only as defined in the appended claims.

What is claimed is:

1. A refrigeration system comprising:

- (a) a container for containing a liquid gas,
- (b) a continuous fluid circuit for containing a vaporizable refrigerant having a condenser section disposed in heat conduction relationship with said container and a vaporizer section,
- (c) a gas driven pump means disposed within said fluid circuit for circulating said refrigerant through said

- fluid circuit for causing said refrigerant to be liquified by passage through said condenser section,
- (d) a conduit communicating with the interior of said container and connected to said pump means for exhausting vapor from said liquid gas to drive said pump means, and
- (e) ventilating means for forcing a flow of air across said vaporizer section for causing said refrigerant to be vaporized therein to cool said air.
2. A refrigeration system according to claim 1 including a controllable valve disposed within said conduit for controlling the operation of said pump means.
3. A refrigeration system according to claim 1 wherein said condenser section comprises a set of coils wound about said container in heat exchange relation therewith.
4. A refrigeration system according to claim 1 wherein said liquid gas is nitrogen.
5. A refrigeration system according to claim 1 wherein said pump means is disposed within a section of said fluid circuit through which said refrigerant passes in the liquid form.
6. A refrigeration system according to claim 1 including a gas storage tank in communication with said conduit for storing vapor from said liquid gas in excess of that required to operate said pump means and for supplying vapor to said pump means.
7. A refrigeration system comprising:
- (a) a container for containing a liquid gas,
- (b) a continuous fluid circuit for containing a vaporizable refrigerant having a condenser section in thermal contact with said container and a set of coils forming a vaporizer section,
- (c) a gas driven pump means disposed within said fluid circuit for circulating said refrigerant through said fluid circuit for causing said refrigerant to be liquified by passage through said condenser section,
- (d) a gas driven ventilating means for forcing a flow of air across said vaporizer section for causing said refrigerant to be vaporized therein to cool said air, and
- (e) conduit means communicating with the interior of said container and connected to said pump means and said ventilating means for exhausting vapor from said liquid gas and driving said pump means and said ventilating means.
8. A refrigeration system according to claim 7 wherein said conduit means comprises a gas storage tank communicating with the interior of said container and first and second conduits communicating with said storage tank and connected to said pump means and said ventilating means, respectively.
9. A refrigeration system according to claim 7 wherein said conduit means comprises a first conduit communicating with the interior of said container, a second conduit connecting said first conduit with said pump means, a gas storage tank connected to said first conduit, and a second conduit connecting said gas storage tank with said ventilating means.
10. A refrigeration system according to claim 7 including controllable valve means disposed within said conduit means, and control means connected to said valve means responsive to the temperature of said vaporizer section for controlling said valve means.

11. A refrigeration system according to claim 8 including first and second controllable valve means disposed within said first and said second conduits, respectively, and control means connected to said first and said second valve means for controlling said first and said second valve means responsive to the temperature of said vaporizer section.

12. A refrigeration system according to claim 7 including a set of coils communicating at an inlet thereof with the outlet of said ventilating means through which said vapor passing through said ventilating means passes, and an additional gas driven ventilating means communicating with the outlet of said set of coils for being driven by said vapor for forcing a flow of air across said set of coils.

13. A refrigeration system according to claim 8 including a set of cooling coils, a third conduit connecting an outlet of said ventilator means with an inlet to said set of cooling coils through which vapor passing through said ventilator means passes, a fourth conduit having an inlet and an outlet and adapted to be disposed in heat exchange relation with a source of heat interconnected at both said inlet and said outlet thereof with one of said second and said third conduits, means for controllably directing said vapor which passes through said set of cooling coils through said fourth, and an additional gas driven ventilator means communicating with the outlet of said set of cooling coils for being driven by said vapor for forcing a flow of air across said set of cooling coils.

14. A refrigeration system comprising:

- (a) a source of liquid gas,
- (b) a continuous fluid circuit having a condenser section disposed in heat conduction relationship with said source of liquid gas and a vaporizer section,
- (c) a vaporizable refrigerant contained within said fluid circuit is liquified when cooled by said liquid gas in said condenser section,
- (d) pump means disposed within said fluid circuit for circulating said refrigerant through said fluid circuit, and
- (e) ventilating means for forcing a flow of air across said vaporizer section for causing said refrigerant to be vaporized therein to cool the air,
- (f) a set of cooling coils,
- (g) conduit means for connecting said source of liquid gas with said set of cooling coils through which vapor from said liquid gas is passed through said set of cooling coils, and
- (h) additional ventilating means for forcing a flow of air across the set of cooling coils.

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