

June 6, 1961

F. R. HOOP  
REFRIGERATION SYSTEM

2,986,907

Filed June 19, 1958

2 Sheets-Sheet 1

Fig.-1.

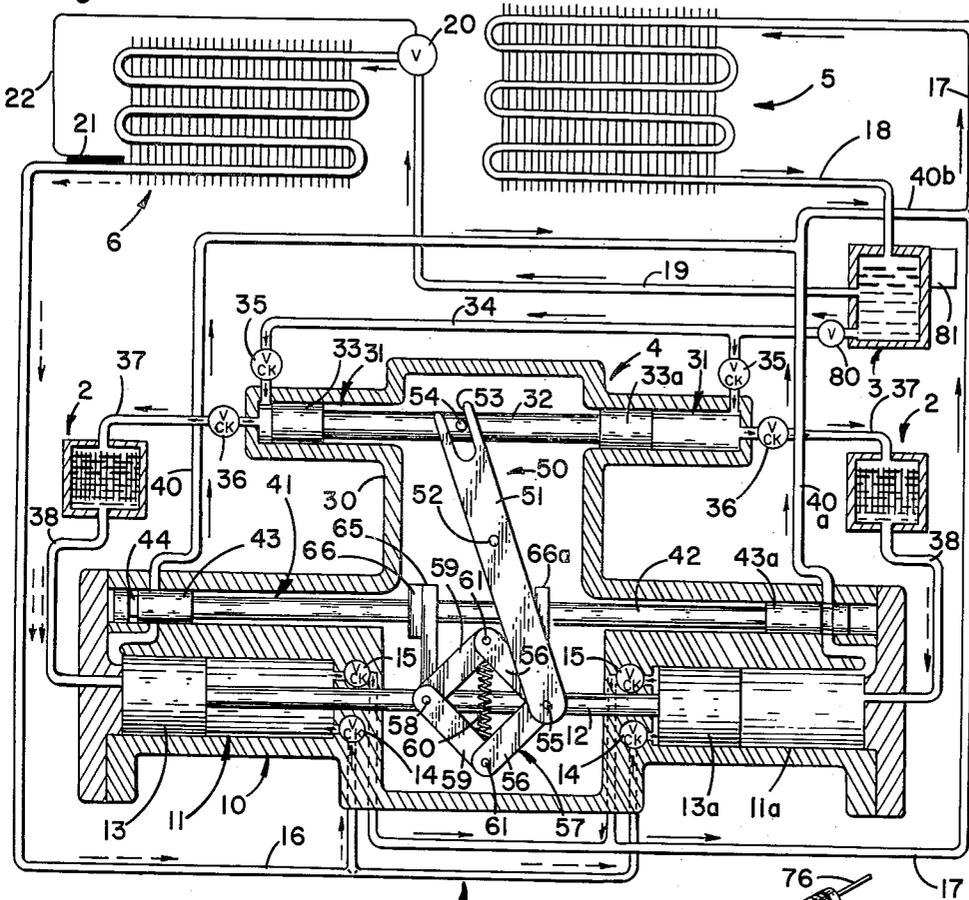


Fig.-2.

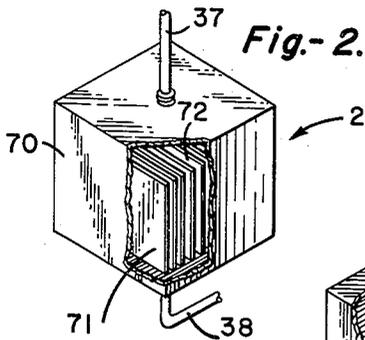


Fig.-3.

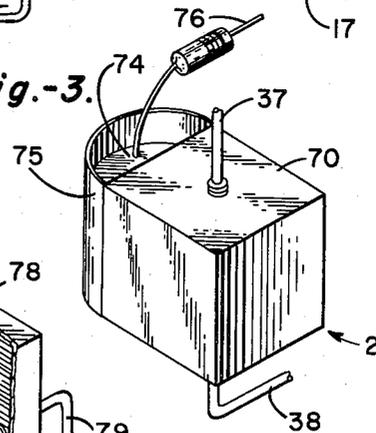
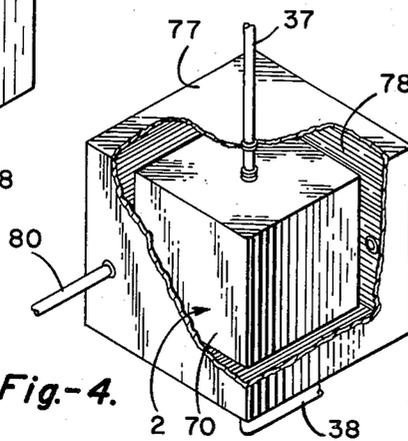


Fig.-4.



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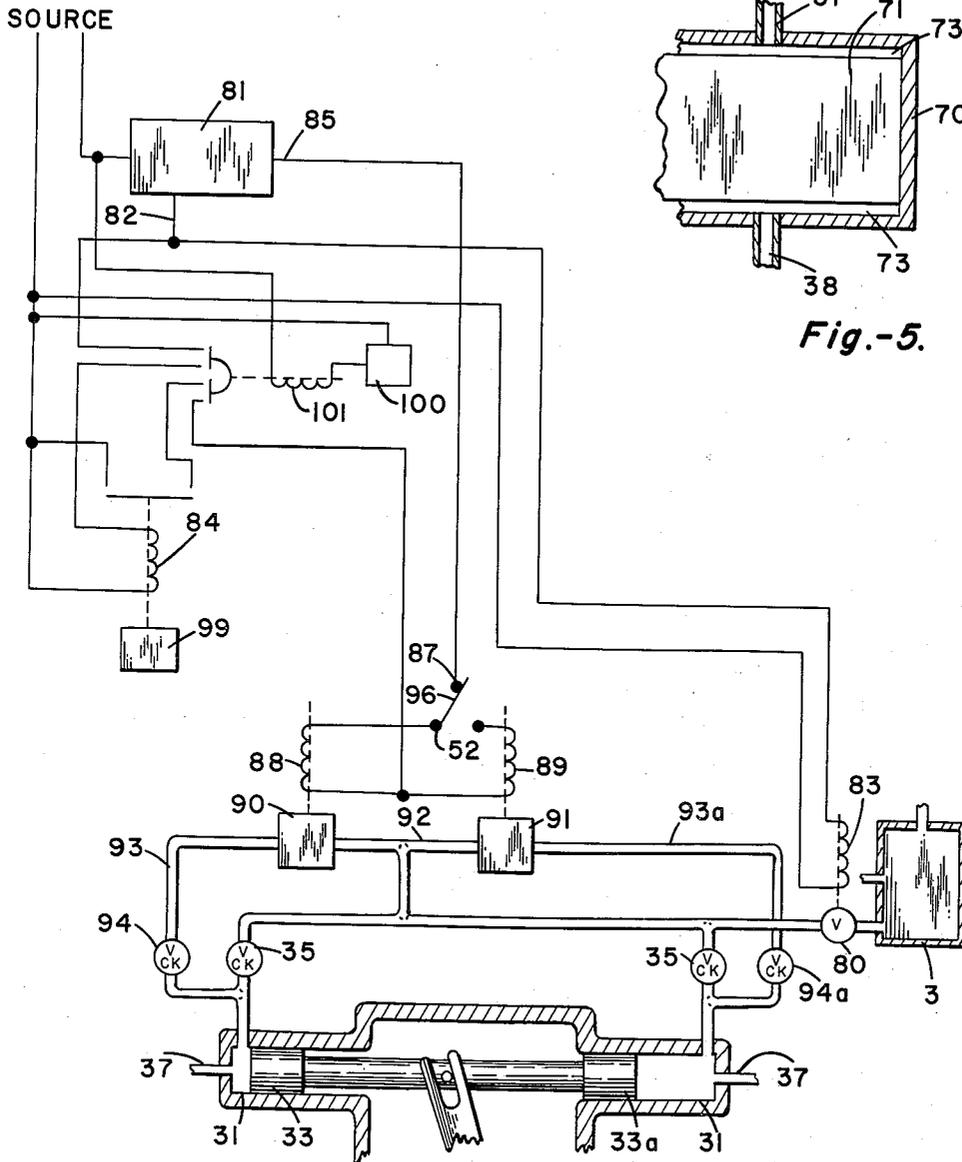


Fig.-5.

Fig.-6.

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**REFRIGERATION SYSTEM**

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7 Claims. (Cl. 62—510)

This invention relates to refrigeration equipment and more particularly to a refrigeration system specifically designed to operate from a low energy source such as hot water or a small capacity electrical heating unit.

All refrigeration systems utilizing a refrigerant which is alternately liquefied and vaporized to effect cooling require some energy source to power them. The most widely accepted power source today is a compressor powered by an electric motor. The only other system having any substantial acceptance is the adsorption system utilizing an open flame as its source of energy. While these systems are satisfactory for a wide variety of purposes they are not practical in a number of applications. These are the situations in which a high energy source for powering the system is either not available or impractical.

Examples of situations in which conventional refrigeration systems do not have a presently satisfactory power source are trucks, railway rolling stock, small boats, passenger cars and aircraft. With the possible exception of railway rolling stock, insufficient electrical energy is available on the vehicles to drive the conventional electrically powered compressor unless special equipment is provided for its generation. This equipment is both expensive and heavy. This is particularly true in the case of aircraft. It also absorbs appreciable quantities of energy which otherwise would be available for the primary purpose for which the vehicle was designed. The use of an open flame such as a gaseous or liquid fueled burner for powering a conventional adsorption system is also not practical in these applications. In the case of trucks, small boats and similar equipment, small internal combustion engines are used for powering the refrigeration equipment. This is expensive, requires substantial maintenance and in many cases is excessively noisy.

The present invention is designed to use a low level of thermal energy such as would be available in hot water or in hot exhaust gases even though they had cooled substantially. It could also be acquired from a low energy electrical source not requiring special heavy duty generating equipment. This invention is particularly adapted to be powered from the hot water of the cooling system of an internal combustion engine. Such hot water is available in aircraft, trucks, passenger cars and small boats. It is also available in most rolling stock for railways in the form of steam, although steam has an energy level far in excess of that required to power this system. A refrigeration system powered in this manner derives all or substantially all of its energy from waste heat sources and thus does not divert energy from the main power plant.

The invention has application to stationary equipment in addition to that of moving vehicles. Many areas, particularly small, remote communities, have insufficient electrical power available for the conventional refrigeration systems and conventional fuels used by the standard adsorption system are of limited availability. This invention provides a system utilizing energy sources which are normally available in such areas. It will be recognized that the invention while particularly adapted for use under the above circumstances is not so limited.

These objectives and others will be understood by those acquainted with the design of refrigeration equipment

upon reading the following specification and accompanying drawings.

In the drawings:

FIG. 1 is a generally schematic presentation of a refrigeration system employing this invention.

FIG. 2 is an oblique, partially broken view of the flash chamber utilized in this invention.

FIG. 3 is an oblique view of the flash chamber utilized in this invention powered by a low energy electrical source.

FIG. 4 is a partially broken oblique view of the flash chamber used in this invention enclosed in a jacket for hot water or gases.

FIG. 5 is a fragmentary, sectional view of the flash chamber illustrated in FIG. 2.

FIG. 6 is a diagram of a system for regulating the operation of this refrigeration system.

In executing the purposes of this invention there is provided a housing having a pair of pistons connected together. Each of the pistons is designed to compress a low flash point refrigerant such as "Freon" ("Freon" is a trademark of the E. I. du Point de Nemours Co., Inc.). As an example of a suitable refrigerant for use with this invention the material dichlorodifluoromethane has been found successful. This material is sold under the trademark "Freon-12." The pistons are powered by measured charges of the refrigerant which are passed through a flash chamber and there substantially instantaneously converted from a liquid to a gas with the resulting expansion in volume used to drive the pistons against the gaseous "Freon" on the other side of the pistons for compressing it. A small injector pump is driven by the pistons to force measured charges of the refrigerant into the flash chamber for driving the system. The flash chamber itself is heated by hot water or hot exhaust gases or by a low energy electrical resistance unit to effect the flashing of the refrigerant. The relationship between the heat exchange surfaces of the flash chamber and its total volume is such that even though very small quantities of refrigerant are introduced the resulting increase in volume from its conversion from a liquid to a gas causes a substantial pressure rise behind the compressor piston. The system also includes a conventional condenser and evaporator.

Referring specifically to the drawings, the numeral 1 refers to a combination motor and compressor. The numeral 2 refers to a pair of flash chambers which receive refrigerant from the reservoir 3 by means of the injector pump 4. The system also includes a condenser 5 and an evaporator 6.

The combination motor and compressor includes a housing 10 having a pair of aligned cylinders 11 and 11a. Extending between the cylinders 11 and 11a is a rod 12 equipped with a piston on each end. The piston 13 is slidably seated in cylinder 11 and the piston 13a is slidably seated in the cylinder 11a. The pistons 13 and 13a divide the cylinders 11 and 11a, respectively, into a motor chamber and a compressor chamber, in each case the motor chamber being outwardly of the piston and the compressor chamber inwardly of the piston.

Each of the compressor chambers has an inlet port connected to a check valve 14, and an outlet port connected to a check valve 15. The check valves 14 are connected by conduits 16 to the exhaust or discharge end of the evaporator 6 and are designed to supply gaseous refrigerant from the evaporator to the compressor chambers. The check valves 15 are both, by means of the conduit 17, connected to the inlet end of the condenser 5. Liquid refrigerant cooled in the condenser 5 is discharged from the condenser into the reservoir 3 through the conduit 18.

Some of the liquid refrigerant in the reservoir 3 is

withdrawn to the evaporator 6 through the conduit 19. An expansion valve 20 is provided in the conduit 19 ahead of the evaporator for regulating the discharge of liquid refrigerant from the reservoir into the evaporator. The expansion valve 20 is not described in detail as it is of conventional construction and any one of a number of such valves now commercially available may be utilized. The operation of the expansion valve 20 is regulated by the thermal element 21 at the discharge end of the evaporator 6. The thermal element 21 is connected to the expansion valve 20 by means of the capillary tube 22. This structure is also conventional and of itself is not a part of this invention except that it constitutes part of the equipment necessary to make a complete refrigeration system.

The housing 10 has an extension portion 30 forming a pair of aligned chambers 31. The chambers 31 form the cylinders for the double acting injector pump 4. The movable member of the injector pump 4 consists of a rod 32 having a piston 33 on one end and a piston 33a on the other end. The pumping chambers 31 and 31a are supplied liquid refrigerant from a common conduit 34 communicating with the reservoir 3. At the inlet port of each of the pumping chambers 31 the conduit 34 has a check valve 35. Refrigerant forced from the chambers 31 by the action of the injector pump 4 is discharged through a check valve 36 and a conduit 37 to one of the two flash chambers 2.

Each of the flash chambers is connected to one of the motor portions of the cylinders 11 and 11a by means of a conduit 38. The motor portions of the cylinders 11 and 11a discharge through the conduits 40 and 40a respectively which themselves discharge into the common conduit 40b. The common conduit 40b discharges into the conduit 17. Adjacent the cylinders 11 and 11a, the conduits 40 and 40a each pass through a sliding valve 41. The sliding valve 41 is equipped on opposite ends with heads 43 and 43a. The heads 43 and 43a are of identical construction each having a circumferential channel 44 which when aligned with one of the conduits 40 or 40a opens the valve to permit the discharge of refrigerant through the conduit.

The combination compressor-motor 1 and the injector pump 4 are operationally interconnected by a lost motion linkage 50. The linkage 50 consists of a lever 51 pivotally mounted about a stationary pin 52. One end of the lever 51 is bifurcated creating a wide, end opening slot 53 which seats about the pin 54 secured to the rod 32 of the injector pump 4. The other end of the lever 51 is pivotally secured to the knee pin 55 of the free linkage pair 56 of the over center toggle linkage 57. The knee pin 58 of the other linkage pair 59 of the toggle linkage 57 is secured to the rod 12 between the pistons 13 and 13a. A spring 60 extends between the pivot pins 61 which secure together the linkage pairs 56 and 59. The operation of this mechanism will be described subsequently.

Also secured to the rod 12 is a finger 65. A pair of spaced stops 66 and 66a are secured to the rod 42 for engagement by the finger 65. The operation of this mechanism will be described subsequently.

Referring to Fig. 2 which shows the structure of the flash chamber 2 in greater detail, the numeral 70 indicates a housing in which is mounted a plurality of pipes or vanes 71. The vanes 71 are positioned in side by side parallel relationship with their ends secured to opposite walls of the housing 70. The vanes are spaced apart to form refrigerant passages 72 between them. The conduit 37 forms the refrigerant inlet for the flash chamber and the conduit 38 the outlet. The vanes 71 are preferably of a material having good heat conductivity characteristics such as copper. The vanes 71 are relatively thin and are closely spaced with the passages 72 having an average width of 0.005 of an inch. The clearance between the housing 70 and the top and bottom ends of the vanes

71 is also kept at a minimum being only that which is sufficient to permit the refrigerant to reach all of the several passages 72.

This flash chamber is designed to provide a rapid heat exchange between the vanes 71 and the refrigerant discharged into it so that the refrigerant is converted from its liquid to its gaseous phase substantially instantaneously. It is also kept at a minimum to insure the discharge of the resulting gaseous refrigerant to the cylinders 11 and 11a rather than its storage within the flash chamber. To this end it has been found that a flash chamber having a heat exchange surface of approximately 70 square inches and a refrigerant holding volume of approximately 0.15 of a cubic inch works satisfactorily. Thus the capacity of the flash chamber for refrigerant is only approximately 0.2% of its heat exchange area. These figures are recited to illustrate proportion and are not to be considered as a limitation upon the actual dimensions of the flash chamber. The functional importance of this will be brought out subsequently.

The heat exchanger may be heated by any suitable means but because of the nature of the refrigerant and the rapid heat exchange inherent in the structure, a low energy level heat source is all that is required. As illustrated in FIG. 3 the heat source may be a small electrical resistance element 74 mounted at one end of the housing 70. This element is enclosed in a shield 75 and energized through the electrical wiring 76. A heating element operating on 6 volts and consuming about 5 amperes will be sufficient to operate the flash chamber 2 satisfactorily.

FIG. 4 illustrates the flash chamber energized by different means. In this arrangement the housing 70 is surrounded by a jacket 77 spaced from the housing 70 to form a compartment 78 encompassing the housing 70. As illustrated, the jacket is designed to be filled with hot water supplied through the conduit 79 and discharged through the conduit 80. It will be recognized that by enlarging the conduits 79 and 80 to accommodate a gaseous medium, exhaust gases may be passed through the compartment 78 for the purpose of heating the flash chamber 2.

The flash chamber 2 has a distinct advantage over the conventional boiler type of liquid to gas phase conversion unit and a conventional boiler is constantly maintained at a pressure level equal to that required to operate the energy converted. This necessitates an injector system for the boiler capable of forcing liquid into the boiler against this back pressure. In the flash chamber 2, the pressure rises to the requirements of the energy converter only momentarily and the liquid can be injected substantially instantaneously at a substantially lower pressure.

Another advantage of the flash chamber is its short starting time. A boiler must be heated to operating temperature together with its contents. In the flash chamber only the heat exchange surfaces need to be heated to operating temperature while the chamber is empty. This requires substantially less energy and consequently the starting time is but a fraction of that required for conventional boilers. The necessity for float or other liquid level controls is also eliminated.

#### Operation

To initiate the operation of the system with the mechanism in the position illustrated in FIG. 1, by mechanical or manual means the rod 12 is shifted to the right. This movement draws refrigerant through the check valve 14 and the conduit 16 into the inner end of the cylinder 11a. At the same time refrigerant already in the inner end of the cylinder 11 is discharged through the check valve 15 at the inner end of that cylinder and into the conduit 17 where it is moved to the condenser.

As the rod 12 moves to the right, the toggle linkage 57

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is caused to straighten by the approach of the knee pin 58 to the knee pin 55. This tensions the spring 60. When the knee pin 58 passes beyond the center line of the pivot pins 61 of the toggle linkage, the toggle linkage will immediately reverse. As it does so the lever 51 will be rocked, moving the upper end clockwise. This will shift the injector pump 4 to the right forcing a charge of refrigerant into the right hand flash chamber 2. At the same time the finger 65 will contact the stop 66a shifting the slide valve 41 to the right closing off the exhaust line 40a and opening the exhaust line 40. The quantity of refrigerant discharged into the right hand flash chamber will be substantially instantaneously heated above its boiling point and will change from its liquid to its gaseous phase applying power to the outer end of the piston 13a. This will reverse the direction of movement of the motor-compressor, causing it to shift once again to the left.

As the injector pump 4 shifts to the right in this operation, the check valve 35 will prevent the refrigerant in the rightmost cylinder 31 from returning to the reservoir 3. The check valve 36 will prevent the expanded refrigerant in the flash chamber from returning to the injector pump. The injector pump 4 is so designed that on each operation it will discharge into one of the flash chambers 2 a predetermined measured quantity of refrigerant which is just sufficient to supply the energy required to operate the combination motor and compressor 1.

The charge of refrigerant discharged into the flash chamber 2 will, by reason of the flash chamber's heat exchange surface area, be substantially instantaneously heated to its boiling point and thus caused to enter its gaseous phase. In changing phases from liquid to gaseous the refrigerant will expand many times in volume. This builds up high pressure within the flash chamber and its connecting lines 38 and 37 at all points downstream of the check valve 36. As the piston 13a moved to the right, gaseous refrigerant was drawn through the check valve 14 and the conduit 16 into the inner portion of the cylinder 11a. The movement of the piston 13a to the left will cause the check valve 14 to close and the check valve 15 to open and the trapped refrigerant will be compressed against the pressure of the refrigerant already existing in the condenser 5, reservoir 3, and connecting lines behind the expansion valve 12. This compressed refrigerant is forced through the check valve 15 into the conduit 17.

As the pistons 13 and 13a near the end of their stroke to the left as the mechanism is illustrated in FIG. 1, the pin 58 secured to the rod 12 will be carried to the left past the center line extending between the pivot pins 61 of the toggle linkage 57. The toggle linkage at this point will be vertical with the links aligned and the knee pin 55 will be to the left in the opposite position from that illustrated in FIG. 1. As soon as the pin 58 moves to the left of the center line between the pins 61 the spring 60 which will have been tensioned will assume control of the toggle linkage causing it to open once more, but in so doing it will cause the knee pin 55 to move substantially instantaneously to the right. This will rock the lever 51 into the position shown in FIG. 1. This movement will cause the injector pump 4 to shift to the left discharging a charge of liquid refrigerant into the left one of the flash chambers 2. This will force the expanding gas into the cylinder 11 causing the pistons 13 and 13a to reverse direction and move once again to the right. As the pistons 13 and 13a have been moving to the left refrigerant will be drawn into the inner end of the cylinder 11 through the check valve 14 from the conduit 16.

Also, as the pistons 13 and 13a and the rod 12 have moved to the left the finger 65 will have come in contact with the stop 66 shifting the valve 41 to the left. This will close the exhaust conduit 40 for the outer end of the cylinder 11 and open the exhaust conduit 40a for the outer end of the cylinder 11a. Refrigerant trapped in the outer portions of the cylinder 11a will be compressed and forced through the conduits 40a and 40b back into the

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conduit 17 and eventually to the condenser 5. When the pistons 13 and 13a move to the right the shifting of the valve 41 will be caused by contact between the finger 65 and the stop 66a.

It will be seen that in this operation it is important to have a highly efficient flash chamber. The flash chamber must operate substantially instantaneously upon the refrigerant to elevate its temperature to its boiling point and thus change its phase from liquid to gaseous. Further, it is essential that the flash chamber have no excess capacity for refrigerant so that the expansion in volume of the refrigerant so that the expansion in volume of the refrigerant incident to its phase change will result in high pressures in the outer portions of the cylinders 11 and 11a where its energy can be utilized for the purpose of compressing other refrigerant. A flash chamber so constructed that it will absorb any appreciable quantity of volumetric change in the refrigerant will not be sufficiently efficient to operate this system. The same observation holds true for a flash chamber having insufficient heat exchange surface to raise the temperature of the refrigerant rapidly. This is particularly true since a low energy thermal source is to be used as the primary source of power for the system. The heat exchange must be rapid and must involve heat exchange contact between the heated vanes or elements and the body of the refrigerant throughout substantially the entire mass of refrigerant injected into the flash chamber.

Various means may be used to start and regulate the operation of this system. The simplest means of starting the equipment is by securing a suitable handle or lever to the rod 12 so that it may be manually shifted to initiate the operation of the equipment once the flash chambers have been heated to operating temperature. Operation may be stopped by means of valve 80 shutting off the supply of refrigerant to the injector pump 4.

In order to illustrate a complete embodiment of this invention, an automatic safety pressure sensitive control system for this device is illustrated in FIG. 6. In FIG. 6 the pump pistons 13 and 13a and cylinders 31 are schematically illustrated.

Now referring to FIG. 6 power is received through the lines 100 and 101 from a suitable source. These lines are connected to the pressure switch 81. The pressure switch 81 is mounted on the reservoir and is designed to turn off the mechanism when the pressure of the refrigerant reaches a predetermined maximum and to start the mechanism when the pressure reaches a predetermined minimum. When the pressure reaches the preset maximum, the circuit 82 which has been open is closed energizing the solenoid 83 closing the valve 80 in the conduit 34. This shuts off the supply of refrigerant to the injector pump 4, resulting in power failure for the motor-compressor 1. At the same time closing of circuit 82 causes the normally open relay 84 to close.

Simultaneously with the closing of circuit 82, circuit 85 which has been closed is opened. Circuit 85 supplies electrical energy to the bipole switch 87 one pole of which is connected to solenoid 88 and the other to solenoid 89. A refrigerant primer pump 90 is operated by the solenoid 88 and a second primer pump 91 by solenoid 89. The pumps 90 and 91 receive refrigerant from conduit 34 through the common conduit 92. The pump 90 discharges through conduit 93 and check valve 94 to cylinder 31 housing piston 33. Pump 91 discharges through conduit 93 and check valve 94a to cylinder 31 housing piston 33a.

The movable member 96 of the bipole switch 87 is secured to pin 52 which, in this case, is secured to lever 51. Thus the position of the member 96 is determined by the position of lever 51.

When the pressure of the refrigerant reaches the pre-selected minimum the pressure switch 81 opens the circuit 82 and closes the circuit 85. Opening of circuit 82 releases the solenoid 83 opening the valve 80. The open-

ing of circuit 82 permits relay 84 to open. However, the opening of relay 84 is momentarily delayed by the retarding device 99.

With circuit 85 and relay 84 closed momentarily one of the solenoid actuated primer pumps 90 or 91 will be actuated. The particular pump actuated will be determined by the position of the bipole switch 87 which, in turn, is controlled by the position in which the motor-compressor stopped. The actuation of the primer pump will force a measured quantity of refrigerant into the one of the flash chambers 2 supplying the cylinder into which the motor-compressor 1 is biased. This will start the motor-compressor. By this time the relay 84 will open, deactivating the primer pumps 90 and 91. As these pumps return to their normal position they will automatically become charged with refrigerant for the next start. The interruption of the circuit through switch 87 increases the life of this switch by eliminating arcing during the operation of the motor-compressor 1.

The circuit 85 is wired in parallel with the thermostat 100 sensitive to the temperature of the medium being cooled by the apparatus. The thermostat 100 regulates the relay 101 which is open when further cooling is not required. The relay 101, when open, interrupts the circuit 85 and that portion of the circuit 82 controlling the relay 84. Since the relay 84 opens when circuit 82 is closed it is necessary to prevent the actuation of relay 84 until both the pressure sensitive safety control switch 81 and the thermostat require actuation of the compressor.

It will be recognized that various other operational control mechanisms may be provided for this system, since the actual control mechanism forms no part of the invention itself.

While this system is particularly designed for a low energy heat source it will be recognized that a concentrated high energy source such as a flame may be used to supply thermal energy to the flash chambers 2. It will also be recognized that the flash chambers 2 are adapted to supply high pressure gaseous energy to various types of energy converters. Such converters are not necessarily limited to those of the reciprocating type.

This invention provides a compact, lightweight refrigeration system specifically designed to operate from a low energy source. It is particularly adapted to use under circumstances where the more conventional power sources for refrigeration systems are either not available or impractical.

While the preferred embodiment of this invention has been described, it will be recognized that various modifications may be made in the invention without departing from the principles thereof. Such modifications are to be considered as covered by the hereinafter appended claims unless these claims by their language expressly state otherwise.

**I claim:**

1. In a refrigeration system adapted to utilize a refrigerant having a low boiling point, the combination comprising: a source of liquid refrigerant; a heated flash chamber capable of substantially instantaneously flashing refrigerant; a housing defining a cylinder; a piston in said cylinder operatively connected to a refrigerant compressor adapted to compress refrigerant in one direction of movement of said piston; first means for urging a measured quantity of liquid refrigerant from said refrigerant source into said flash chamber; second means for conducting gaseous refrigerant from said flash cham-

ber to said cylinder for urging said piston in said one direction; a condenser and third means for conducting refrigerant from said compressor to said condenser; an evaporator receiving refrigerant from said refrigerant source; fourth means for returning refrigerant from said evaporator to said compressor.

2. A refrigeration system as described in claim 1 wherein said flash chamber is heated by hot water.

3. A refrigeration system as described in claim 1 wherein said flash chamber is heated by water having a temperature in the range of 150°-212° F.

4. A refrigeration system as described in claim 1 wherein said flash chamber is heated to a temperature in the range of 150°-212° F.

5. A refrigeration system as described in claim 1 wherein said flash chamber has a plurality of heat exchange surfaces having passages for refrigerant therebetween and the combined volume of said passages is approximately 0.2% of the combined areas of said heat exchange surfaces.

6. A refrigeration system as described in claim 1 wherein said first means is an injector pump adapted to receive liquid refrigerant from said refrigerant source; a motion transfer element operatively connected at one of its ends to said piston and at the other of its ends to said injector pump and adapted to drive said injector pump.

7. In a refrigeration system adapted to utilize a refrigerant having a low boiling point, the combination comprising: a source of liquid refrigerant; a pair of flash chambers each capable of substantially instantaneously flashing refrigerant; a pair of aligned cylinders each having a piston reciprocally received therein; an element connecting the inner ends of said pistons; first means connecting the outer ends of each of said cylinders to one of said flash chambers; a condenser and an evaporator; second means connecting the inner ends of each of said cylinders to said condenser; third means connecting the inner ends of each of said cylinders to said evaporator; a double acting reciprocating injector pump and a link operatively connecting said element to said pump and adapted to move said pump in one direction on each stroke of said pistons; said link having a lost motion connection therein whereby said pump is actuated only during the final portion of travel of said pistons in each direction; said pump having a pair of receiving ports connected to said refrigerant source and a pair of discharge ports, each of said discharge ports being connected to one of said flash chambers, and check valve means associated with each of said ports to allow refrigerant flow only in a direction from said source to said pump and from said pump to said flash chambers, whereby as said pump is reciprocated a quantity of liquid refrigerant is delivered alternately to each of said flash chambers.

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UNITED STATES PATENT OFFICE  
CERTIFICATE OF CORRECTION

Patent No. 2,986,907

June 6, 1961

Frederick R. Hoop

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 2, line 22, for "du Point" read -- du Pont --;  
column 2, lines 62 and 63, strike out "and an outlet port  
connected to a check valve 14"; column 6, lines 12 and 13,  
strike out "so that the expansion in volume of the refrigerant"

Signed and sealed this 28th day of November 1961.

(SEAL)

Attest:

ERNEST W. SWIDER

Attesting Officer

DAVID L. LADD

Commissioner of Patents

USCOMM-DC