United States Patent [19]

Miller

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[45] ***Jan. 29, 1974**

[54] **THERMODYNAMIC CYCLES**

[75] Inventor: **David T. Miller,** Torrance, Calif.

[73] Assignee: **Statham Instrument, Inc.,** Oxnard, Calif.

[*] Notice: The portion of the term of this patent subsequent to Sept. 26, 1989, has been disclaimed.

[22] Filed: **Aug. 12, 1971**

[21] Appl. No.: **166,316**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 75,337, Sept. 25, 1970, Pat. No. 3,693,370.

[52] **U.S. Cl.** **62/175,** 60/26, 62/332, 62/384, 62/467

[51] **Int. Cl.** **F25b 25/00**

[58] **Field of Search** 62/87, 116, 117, 118, 332, 62/333, 334, 467, 498, 501, 175; 60/26

[56] **References Cited**

UNITED STATES PATENTS

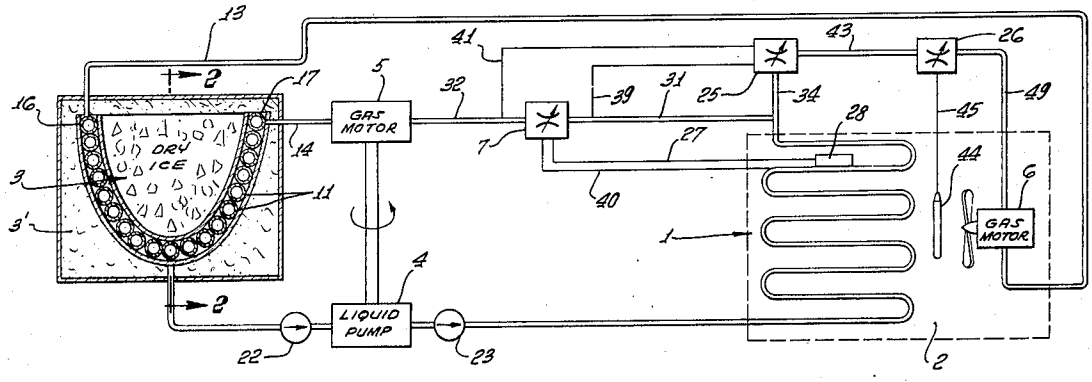
2,009,372	7/1935	Moore	62/118 X
2,175,267	10/1939	Killeffer	62/87
3,693,370	9/1972	Miller	62/332 X

Primary Examiner—William F. O'Dea
Assistant Examiner—Peter D. Ferguson

[57] **ABSTRACT**

This invention relates to thermodynamic cycles operating between two levels of subatmospheric temperature, whereby power is generated and/or refrigeration obtained, in which a heat transfer liquid is employed having a relatively high vapor pressure at atmospheric temperature.

23 Claims, 10 Drawing Figures



PATENTED JAN 29 1974

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SHEET 1 OF 3

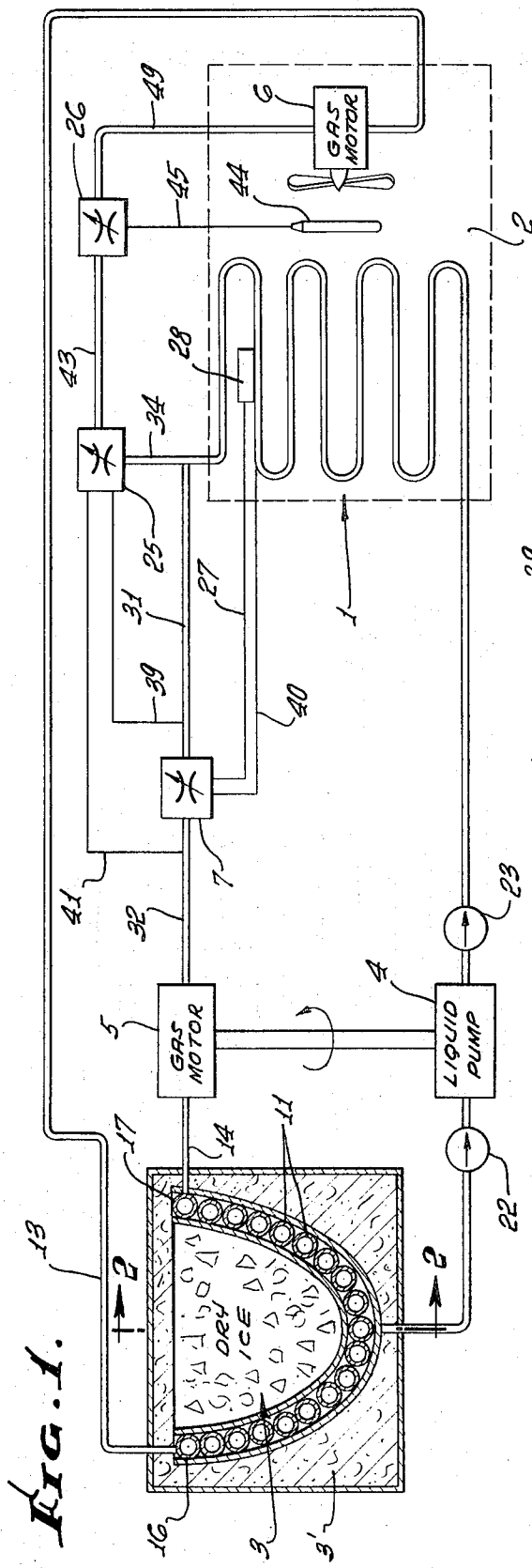


FIG. 1.

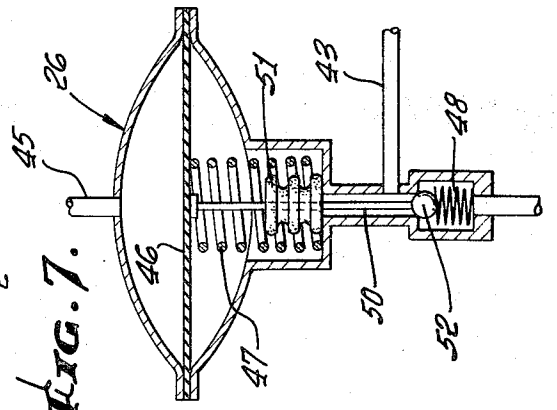


FIG. 7.

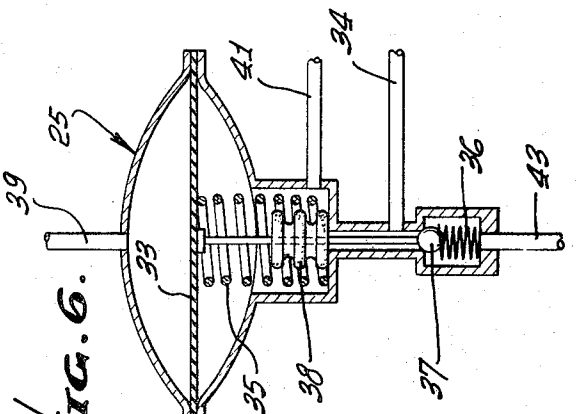


FIG. 6.

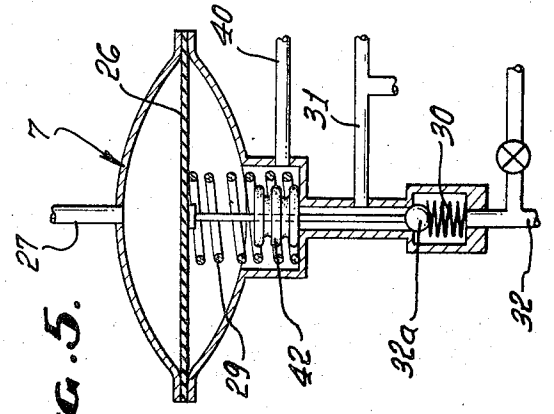


FIG. 5.

INVENTOR.
DAVID T. MILLER
BY Kendrick & Subkow
ATTORNEYS.

FIG. 2.

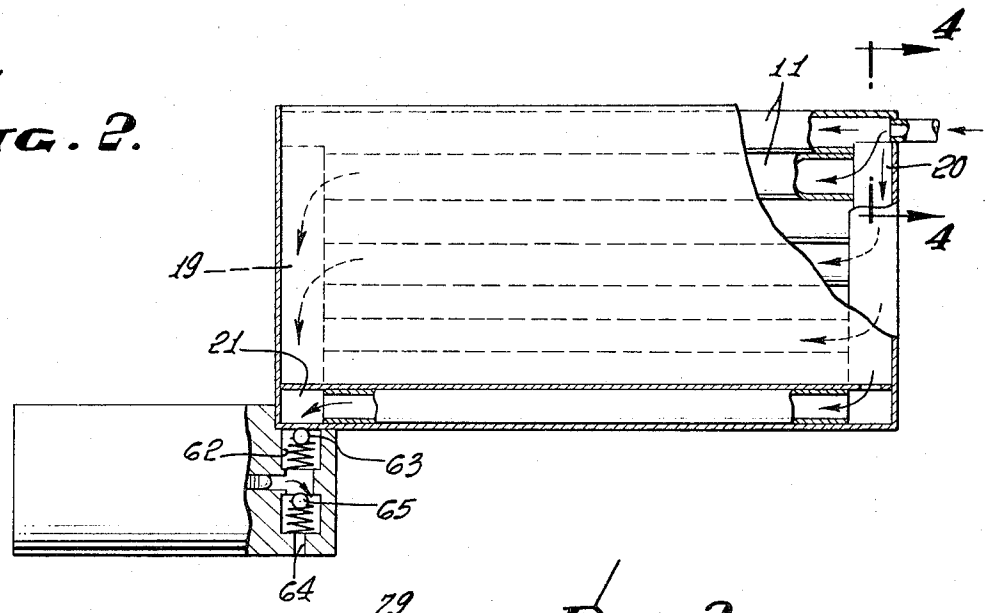


FIG. 3.

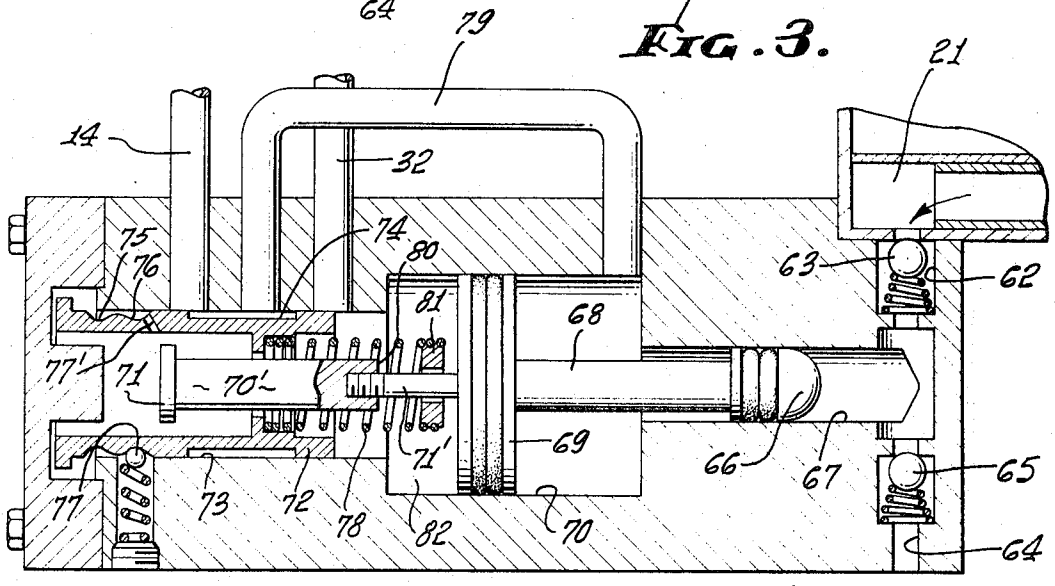


FIG. 4.

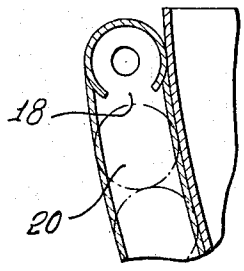
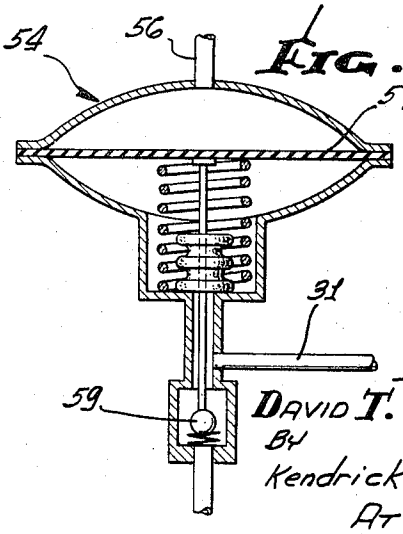


FIG. 10.



INVENTOR.
DAVID T. MILLER
BY
Kendrick & Subkow
ATTORNEYS.

FIG. 8.

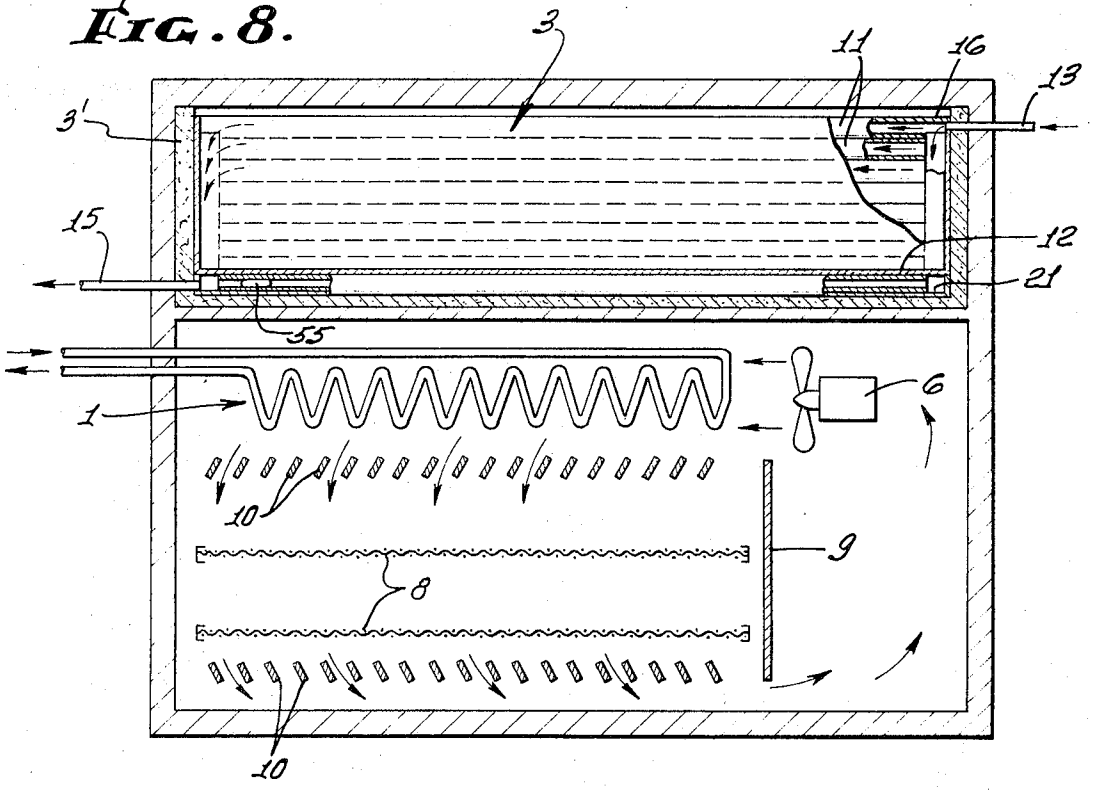
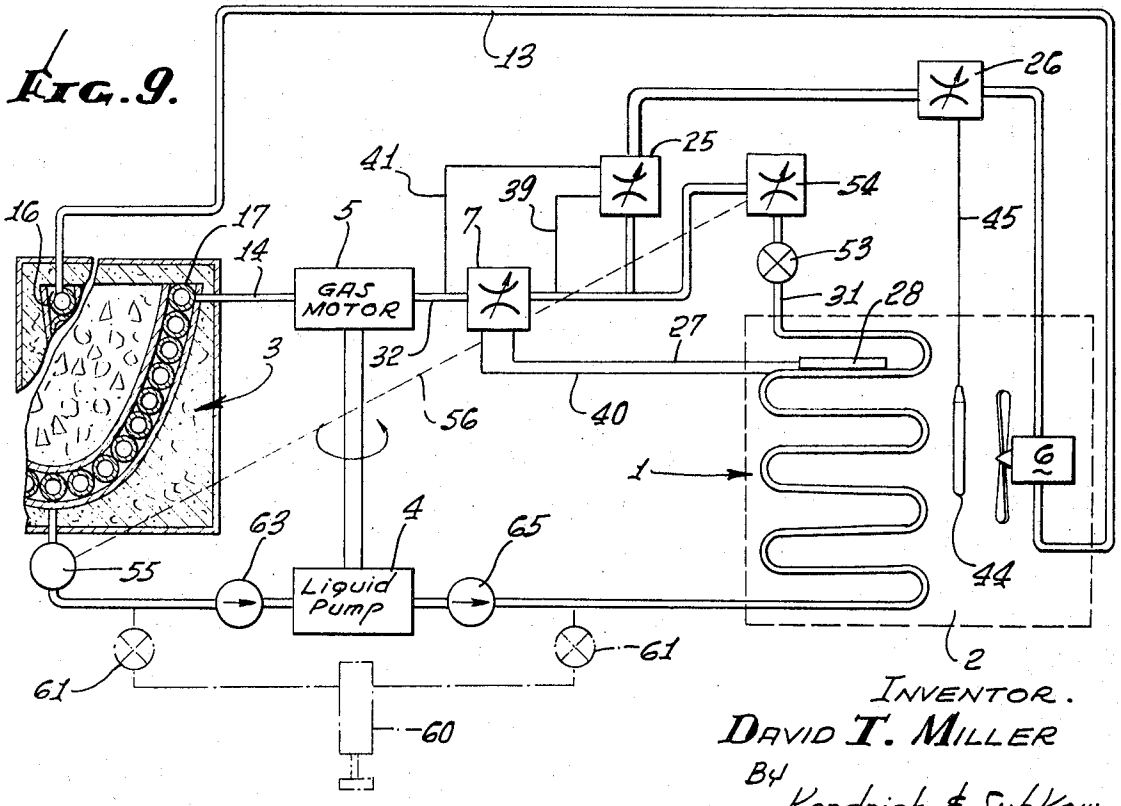


FIG. 9.



INVENTOR.
DAVID T. MILLER
BY
Kendrick & Subkow
ATTORNEYS.

THERMODYNAMIC CYCLES

This application is a Continuation-in-Part of my application Ser. No. 75,337 filed Sept. 25, 1970 now Pat. No. 3,693,370.

BACKGROUND OF THE INVENTION

In the conventional Rankine cycle, the system operates at superatmospheric temperatures. In such cycles, the high temperature stage, sometimes referred to as the "boiler" is maintained by the expenditure of energy either chemical or nuclear in form. This energy source forms the consumable energy portion of the cycle. The necessary rejection of heat to the atmosphere involved in the very nature of the conventional Rankine cycle contributes to its relatively low thermal and economic efficiency. Additionally, the relatively high temperature base of the cycle in addition to its low efficiency requires a large capital expenditure per horsepower of usuable energy.

SUMMARY OF MY INVENTION

In the preferred embodiment of my invention, I employ, as a means of vaporizing the operating liquid, a heat transfer system employing the ambient atmosphere as the heat source to cause vaporization of a liquid whose boiling point is substantially below ambient temperature. The vapor passes to a condenser operating at substantially low subatmospheric temperature due to presence of a heat sink wherein the vapor is condensed. The condensate is pumped from the relatively low pressure condensation zone into the vaporization zone which is at substantially higher pressure than the condensation zone. The power employed in transferring the condensate to the vaporization zone is derived from the high pressure vapor source of the evaporator. Such means may be an injector which passes condensate into the evaporator. I prefer, however, to use a pump in which the motive power is derived from the relatively high pressure vapor generated in the evaporator, the exhaust vapor from the pump is introduced into the condenser in a closed cycle without any exhaust to the atmosphere.

The system of my invention may be a source of refrigeration. The evaporator abstracts heat from the ambient atmosphere and thus causes refrigeration in the surrounding atmospheric space.

Alternatively, or in addition, I may employ a portion of the high pressure vapor source from the evaporator to operate an engine for the generation of power and the exhaust from the engine may also be introduced into the condenser in a closed cycle.

It will be seen that the energy expended in this cycle, which has economic value is only that consumed in the condensation stage of the cycle since the energy absorbed in the evaporation stage is derived from the ambient atmosphere. The economic cost of the power depends on the economic cost of the cooling medium and where the cooling medium is of negligible cost the power generator has a cost based on operating cost which may be substantially zero.

The heat abstracted from the atmosphere in the evaporator stage is returned to the heat sink medium in the condensation stage, both of which operate at temperatures below the temperature of the heat source which is the atmosphere. This is distinguished from the conventional Rankine cycle in which low efficiency is

largely dependent upon the loss of heat to the atmosphere in the high temperature stage and the prime movers and also in the low temperature stage, all of which are at a temperature above the atmospheric heat sink. For this reason, I have denominated my unique cycle an "Inverted Rankine Cycle" to distinguish it from the conventional Rankine cycle.

In my preferred embodiment, I employ the cycle as a refrigerating means and employ dry ice as the cooling medium that is heat sink in the condenser.

The liquid medium employed as the heat transfer medium should, therefore, have a boiling point substantially above the temperature of the solid carbon dioxide, which at 760 mm has a sublimation temperature of about −78°C. The liquid medium should have a boiling point substantially below the ambient temperature. In the case of refrigeration, this is preferably below about 50°C in the case of food storage. For example, I may use Freon-12, which is a material sold by Du Pont De Nemours Co., and said to be dichloro-difluro-methane having a boiling point at 760 mm pressure of −29°C.

It is another object of my invention to provide control systems which has the function of controlling the level of the liquid in the evaporator.

It is another object of my invention to provide means for regulating the vapor flow to the motors sufficient to provide the required feed to the motor for the liquid circulating pump irrespective of the demand by the motor for the blower or other auxiliary equipment.

It is also an object of my invention to provide means to control the air circulation rate when the temperature in the system rises or falls below a predetermined point.

It is a further object of my invention to provide means to initiate the start up of this system.

It is the further object of my invention to provide a pump which is of such design and is so positioned in the system as to be a further aid in the control of the system.

As a result of these controls, which may but need not all be employed, as will be more fully described below, the system of my invention arranges the use of available excess power in starting the cooling cycle and circulation of the system.

The system also manages the condenser and evaporator efficiency by controlling the level of the liquid in the evaporator. The system is able to handle large overloads and permits the reestablishment of desired refrigeration conditions when these conditions are upset by any extreme use or defect.

DETAILED DESCRIPTION

FIG. 1 is a partially schematic view of the system of my invention.

FIG. 2 is a partially schematic view with the condensation zone shown on the section taken on line 2—2 of FIG. 1.

FIG. 3 is a vertical section taken through the pump of my invention showing its position at the condensation zone.

FIG. 4 is a fragmentary sectional view on line 4—4 of FIG. 2.

FIGS. 5, 6, 7 and 10 are sectional views partly schematic of the valves employed.

FIG. 8 is a schematic view showing the relation of the various parts of the elements of the system of my invention.

FIG. 9 is a schematic view of a modification of the system of FIG. 1.

One of the features of my invention, which is a material addition to the utility of the cycle described above, is the control which is made possible by the control system of my invention.

While any form of pump may be used as the pump and any form of prime mover may be used which will be operated by the vapor from the evaporator, the motor-pump assembly with the evaporator described above is a useful aid in attaining the controls made possible by the system of my invention.

One of the controls which I have found to be useful is a level control which guards against flooding of the evaporator and the introduction of liquid from the evaporator into the rest of the system. It also acts to guard against too high a level of liquid in the evaporator.

The unit is illustrated by valve 7 FIG. 1. This control operates to increase the vapor flow from the evaporator when the liquid level falls below a predetermined level in the evaporator and decreases the vapor flow to the condenser when the level in the evaporator rises above a predetermined point. This variation may be made small so that the liquid level is maintained substantially constant.

I may and preferably do also provide a further control which is modulated by the action of the level controller in the sense that when the flow of vapor to the condenser is increased the control assures that there is sufficient pressure in the system to drive the pump delivering liquid from the condenser to the evaporator. This control is illustrated by the valve 25 of FIG. 1. This unit may be omitted when the variation in liquid level in the evaporator normally encountered is within a tolerable range so that there is always a residual pressure in the system to operate the motors. It does, however form a useful and is a prefered precautionary control and I prefer to employ this control where the refrigeration unit may enter relatively unknown operating conditions.

A third control which is useful in the control system of my invention is to control the temperature in the ambient space over the evaporator coils. This control modulates the evaporator pressure to the blower motor to increase the flow when the temperature in the ambient space rises and to decrease the vapor flow to the blower motor when the temperature falls below the desired point. This unit is illustrated by valve 26.

FIG. 1 illustrates, schematically, the principles of my invention. The evaporator 1 is exposed to ambient temperature in the space 2 surrounding the coil of the evaporator. The liquid contained in the cycle has a boiling point to be vaporized at the ambient temperature at the pressure contained in the coil 1. The condenser 3 is maintained at a temperature below that in the ambient space 2 surrounding 1 by means of a cooling system which will result in the desired low temperature in the space surrounding the condenser coil 3. The vapor condenses at the lower pressure attained in the condensation zone and the condensate liquid is pumped by feed pump 4 into the evaporator 1 against a higher pressure. The pump 4 is operated by a motor 5 which takes its operating vapor from the high pressure vapors derived from 1. The motor 5 may be in the form of a reciprocating engine powered by the vapors generated in the evaporator and from which the exhaust vapors discharge into the condenser 3.

The high pressure vapors may be also used to generate additional power beyond that absorbed by the feed pump motor 5 in keeping the cycle continuously operating. A vapor take-off can be at any suitable position in the high pressure vapor stage and pass to the motor 6 which may be of a positive displacement or turbine kind and the exhaust from motor 6 is introduced into the condenser 3. The motor 6 may be used to circulate the air over the evaporator in the space 2 or drive any power absorbing unit or a generator such as an electrical generator.

In my preferred embodiment, I apply this system to refrigeration in a closed system where the pressure necessary for the efficient operation of the refrigeration system is obtained entirely from the change in enthalpy between the high and low temperature stages including the energy losses in the motors.

A schematic representation of a preferred embodiment of the system of FIG. 1 is shown at FIG. 8 in which the evaporator 1 is enclosed in an insulated chamber forming the ambient space 2. The condenser 3 is mounted in an insulated box. As shown in FIG. 8 the condenser 3 is mounted in an insulated chamber 7 positioned in a unitary arrangement with the evaporator. The evaporator unit 1 is mounted adjacent the top of the lower chamber, and the fan and motor 6 is mounted to circulate air over the coils 1 and over and through the travs 8 aided by suitable baffles 9 and louvers 10. The tubes 11 are positioned in the jacket 12 of the dry ice chamber of condenser 3. The line 13 connects to the top tube 16 and the line 14 connects to the tube 17, one on each side of the dry ice chamber. The tubes 11 extend across the length of the condenser and are provided with end slots 18 (See FIG. 4) to permit entry of liquid into the plenums 19 and 20 (See FIG. 2) The tubes 11 are stacked one on top of another and may be brazed for rigidity. They are mounted in the condenser jacket 12 and are open at both ends at the plenums 19 and 20 to discharge into the plenums. The liquid condensate collects in the bottom 21 of the plenums and is pumped through line 15 by pump 4 via check valves 22 and 23 and introduced into the evaporator 1.

The valve 7 is shown in FIG. 5. The space above the diaphragm is connected by pipe 27 to the bulb 28 of a temperature sensor which is positioned to be in temperature equilibrium with a selected portion of the coils of the evaporator. It is shown schematically in FIG. 1. The sensor may be any well known temperature sensing device known to the prior art which will generate a predetermined pressure in line 27 proportional to the temperature in the evaporator tube at the location where the bulb is positioned.

The temperature sensitive device 28 is in direct contact with the metallic tubes of the evaporator 1 at the upper portion thereof and the pressure in line 27 connected to the temperature sensitive device 28 responds as a direct function of the temperature in the evaporator tubes at the temperature sensitive device 28. The pressure through 27 is exerted in the diaphragm chamber on the diaphragm 26 and is opposed by the bias of the spring 29 and spring 30 and the gas pressure through 40 connected to the evaporator adjacent 28. Line 32 connects the valve to the input of the gas motor 5. The diaphragm 26 actuates the valve 32a

sealed by bellows seal 42 to control the communication between the pipe 31 and 32. The pressure difference between 27 and 40 is a function of the degree of superheat in the evaporator at the location of 28.

Since the vapor above the liquid in the evaporator is above the boiling point of the liquid, the heat flow from the ambient space adds superheat at 28 will hold the temperature at 28 above the boiling point only if the level has not reached 28. If the liquid level reaches 28, the temperature will fall to the boiling point of the liquid and the pressure in line 27 will fall.

If the liquid level is desired to be maintained at the level of the sensor 28 the spring biases are set so that the valve member 32 will be depressed to increase the opening when the pressure in line 27 is increased beyond a predetermined limit and moved to reduce the valve opening when the temperature at 28 decreases and the pressure in 27 decreases. The valve opening is thus increased as the degree of superheat in the vapors at 28 is increased and the valve opening is decreased as the degree of superheat is decreased and is completely closed when the liquid has reached the sensor 28 and the temperature at 28 is the boiling point of the liquid which has reached 28.

The valve 25 is a demand control valve. Its purpose is to permit the development of sufficient pressure in the system to operate the pump 4 irrespective of the demand of the gas motor which drives the auxiliary equipment such as the fan.

If valve 7 is completely opened valve 25 will close to shut off the blower.

Valve 26 (see FIG. 7) is used to control the operation of the gas blower responsive to the temperature in the ambient space. A temperature responsive device 44 similar to device 28 is placed at some point which is intended to be the control point. The line 45 connects to the valve above the diaphragm 46 to generate a pressure responsive to the temperature at 44. The diaphragm is biased by spring 47 and 48 and is connected to the valve 52 by a rod 50 passing through an isolation bellows 51 to the valve member 52.

If the temperature at 44 rises above a predetermined low temperature the valve member 52 will move to connect line 43 to line 49 to operate the motor of the fan and when the temperature falls to a predetermined point it will cause the valve to close cutting off communication to the fan motor.

I have provided the optional valve 25 which may be used. (See FIG. 6) The added valve 25 is an advantage where large surges of temperature in the ambient space is encountered but may not be necessary when the temperature maintained in the space 2 is reasonably stable. In such case the diaphragm chamber above the diaphragm 33 is connected by line 39 to the line 31 at the input to the valve 7 and line 41 is connected to line 32 at the output of the valve 7. The line 34 connected to the evaporator is connected down stream of the bellows seal 38 at the input side of valve 25 and line 43 is connected to the output side of the valve 25. The pressure difference between 39 and 41 is that established by the valve 7. The spring bias of the springs 35 and 36 is designed so that the valve will close when the pressure difference between 39 and 41 decreases and will cause valve 37 to be fully closed when valve 32*a* is fully opened. The range of pressure difference between 39 and 41 required to move the valve 37 from a fully opened to a fully closed position may be as small as desired by proper selection of the spring rate and bias.

If valve 7 is less than fully open valve 25 will remain open. Thus valve 25 senses the position of valve 7 and is fully open with no effect on the system unless valve 7 is driven to the full open position indicating that the pressure available for driving the liquid pump 4 is marginal. Under these circumstances valve 25 restricts temporarily all flow to the blower gas motor 6 in order to conserve all available pressure for the pump gas motor 5.

The opening of the valve 26 is made responsive to the temperature in the ambient space 2. The temperture sensor 44 is made responsive to the temperature at a desired location in the ambient space to generate a vapor pressure through line 45 which is responsive to the temperature, increasing with increase in the temperature and decreasing with the fall in temperature at the selected point of the ambient space. Thus pressure is exerted in the diaphragm chamber of 26 above the diaphragm 46. The pressure under the diaphragm may be any desired fixed pressure, for example atmospheric pressure. The diaphragm is biased by springs 47 and 48 and actuates the valve member 49 to control communication between 43 and 49 by means of the valve stem 50 passing through the bellow seal 51 and connected to the valve member 52. It will be seen that with vapor feed through the line 43 the rate of vapor passage to the motor 6 will be proportioned to maintain a predetermined temperature in space 2.

If it is not desired to employ the regulation provided by valve 25 it may be eliminated and line 34 be connected directly to line 43.

FIG. 9 shows an auxiliary control which may be added when it is desired to employ an auxiliary pump to move liquid from the condenser to the evaporator, where the condition of the system is such that the pump 5 is inoperative for any reason. Such a condition may occur on start up of the unit where there is insufficient vapor at the necessary pressure to operate the liquid pump motor.

The system is the same as in FIG. 1 like parts bear like number. In the sustem of FIG. 9 I provide a fourth valve 54 which is connected by the manual valve 53 in line 31 at the discharge end of the evaporator. The valve 54 is shown in FIG. 10 and is similar in construction to the valve 26 of FIG. 7 but is designed to close as the pressure increases above the diaphragm 57. A temperature or pressure sensor 55 is positioned at the discharge end of the condenser 3 (See FIGS. 8 and 9). A sensor such as 44 may be used and the vapor line 56 (similar to 45) is connected to the valve 54 above the diaphragm 57. The valve 59 controls communication in line 31. Valve 53 can be used to shut the system down at any stage of operation. The spring bias of valve 54 is set that so long as the temperature of the condensate at 55 is within the desired operating range for efficient operation of the system, valve 54 remains open. If, however, the temperature at 55 rises above the selected range as for example if the dry ice is depleted, or when first added has not had sufficient time to drop the temperature sufficiently, then the pressure in line 56 rises to close valve 54 thus inactivating the system. It is to be noted that in such case valve 54 is closed, and liquid is trapped in both the evaporator and in the condenser. When the temperature at 55 falls to the operating temperature range as for example when dry ice is replen-

ished, valve 55 will open and the liquid in the evaporator will vaporize and vapor feed through valve 7 will automatically reactivate the cycle. The result of this control assures that liquid is retained in the evaporator and not lost to the condenser during the period that the pump does not move liquid because of insufficient pressure difference across the gas motor 5 to drive the pump.

The pump 60 is an auxiliary pump which may be used when the pressure difference across the gas motor 5 is insufficient to start the system. It may be used for this purpose with or without the presence of the auxiliary valve 54 and the control 55. That is it may be used in the system shown in FIG. 1. The pump 60 bypasses the liquid pump 4, the isolating valve 61 being open, when the pump 60 is used and are otherwise closed.

If the evaporator does not contain liquid for any reason, the auxiliary pump 60 will operate to transfer liquid from the condenser to the evaporator. Upon entry of liquid into the evaporator, the liquid will flash and the system will start. The pump motor will become operative as soon as sufficient liquid is vaporized to establish the required vapor pressure to operate pump 5, and the liquid pump 5 will then operate normally.

It will be noted that the pump 60 is needed only for a very limited number of strokes and acts as a trigger to place the system into operation.

While any suitable pump may be employed as pump 4, I prefer to use a pump operated by a positive displacement motor which is capable of reciprocating at low frequencies and which will avoid being hung at dead center. Such a pump is shown in cross section in FIG. 3.

The inlet 62 is provided with a suitable check valve 63 and the outlet 64 is provided with a suitable check valve 65. The pump piston 66 in pump cylinder 67 is ocnnected to a piston rod 68, which is connected to the power piston 69 in the motor cylinder 70. The pistons are each provided with a suitable seal. The power piston 69 is screw connected to a valve system 70 by pump piston extension 71'. The valve stem 70 carries a flanged head 71. The valve barrel 72, slidably position in the valve cylinder 73, carries an elongated cylindrical groove 74 and circular detent grooves 75 and 76 cooperating with a spring loaded detent 77. The valve barrel is pierced with bores 77'. Push-pull spring 78 is connected at one end to the valve barrel 72 and at the other end to spring retainer 81.

The high pressure inlet line 32, downstream from the valve 7 is connected to the input at the valve cylinder 73 and the exhaust 14 from the pump is connected to the valve cylinder as shown. A by-pass is provided at 79 connecting the grooved space 74 with the space 70 of the power cylinder.

In the position as shown in FIG. 3, showing the position at the completion of the stroke to the left of the drawing as shown, the piston 69 is in position for the initiation of the outbound stroke to the right. The space 70 is connected to the exhaust 14 and the space 82 ahead of the piston 69 is connected directly to the inlet line 32. Cavity 78 is at the same pressure as 82 due to the clearances between the valve stem, spring retainer, spring, valve barrel.

The piston 45 thus starts moving to the right, vapor exhausting through 79, 74 and 14 until the end 80 of the stem 70 engages the spring retainer 81 and the continuing motion of the piston causes a stretching of the spring 70 which continues until the spring tension creates a tractive effort sufficient to overcome the spring tension pressure of the spring loaded detent ball 77. The valve barrel snaps to the right until the detent ball enters the groove 75. In that position the valve barrel has moved to uncover the inlet 32 to register it with the groove 74 closing off 14 and therefore connecting space 70 through the by-pass 79 to the inlet 32. The exhaust outlet 14 is connected to the space 82 through port 77', grooves 75, 76, cavity 78 and the clearances described above.

The piston 69 and valve stem 70 moving to the left releases the spring tension in the spring 78. The continued motion of the piston 69 engages the retainer 81 and the resultant compression of the spring in normal operation is sufficient to overcome the spring loaded detent whereupon the barrel snaps to the position shown in FIG. 3 where the spring loaded detent ball 77 engages the groove 76 to complete the cycle of reciprocation of the piston 69 and the piston rod 68 causes a pumping action of the liquid into 62 and out of 64.

The permissible stroke of piston without inducing a movement of the valve barrel may be controlled by adjusting the length of the rod 71', thus controlling the stroke of the piston.

Because of the presence of foreign substances, the valve barrel may stick so that the spring 78 when it extends to the right develope insufficient force to move the valve barrel and to pull it away from the detent ball 77. In such case, piston 69 will continue to move to the right until the flanged head 71 engages the valve barrel shoulder and the continuing motion of 69 will exert sufficient force to free the valve member barrel and pull it away from the detent ball 77.

Should the valve barrel stick during the inboard motion of the piston to the left, and the compression force on the spring be insufficient to dislodge the valve barrel, the piston 69 will continue its motion to the left until the spring is compressed establishing a solid connection between the piston 69 and the valve barrel to dislodge the barrel, whereupon the expansion of the spring will cause the valve barrel to snap to the position shown in FIG. 3.

Driving the valve barrel by means of the spring force imparts to the system a very large frequency response range so that the valve reciprocates properly at both high and low reciprocation rates.

The driving spring force co-acts with the spring loaded detent to cause the valve system to snap from one position to the other and the valve is not subjected to inertia forces inherent in the piston portion of the system.

The valve therefore cannot be hung up at dead center at the end of either the inbound or outbound stroke.

As shown in FIG. 2 and 3, I prefer to position the intake valve 62 of the pump closely adjacent to and preferably at the outer part of the plemun 21 in order that the heat input into the liquid passing from the condenser into the pump be minimized in order to avoid vaporization of the liquid in the pump cylinder.

I claim:

1. A thermodynamic apparatus adapted to operate between two levels of subatmospheric temperature including an evaporation zone adapted to be exposed to ambient temperature, a condensation zone adapted to operate at a lower temperature, a vapor conduit connecting the evaporation zone with the condensation

zone, a liquid collecting zone connected to said condensation zone, a liquid conduit connecting said liquid collecting zone with said evaporation zone and a pump in said liquid conduit, a vapor motor connected to said pump, a vapor input line to said motor, said line connected to the evaporation zone, an exhaust from said motor connected to said condensation zone and a fan positioned at said evaporation zone, a second motor connected to said fan, a vapor conduit connecting said evaporation zone to said last named motor, an exhaust vapor connection connected to said last named motor and condensation zone, control means to control the heat transfer from the evaporation zone to the condensation zone whereby the pressure required to operate said motors is obtained substantially entirely from the change in enthalpy between the evaporation zone and condensation zone including the energy losses in the motor.

2. In the apparatus of claim **1** in which said condensation zone includes an insulated container for refrigerant, cooling conduits in heat exchange relation to the refrigerant in said refrigerant container.

3. In the apparatus of claim **1,** said evaporation zone comprising a conduit connected to said pump and to said first mentioned vapor conduit, an insulated enclosure for said conduit, said fan mounted for circulation of air over said conduit and in said enclosure.

4. A thermodynamic apparatus adapted to operate between two levels of temperature including an evaporator adapted to be exposed to ambient temperature, a condenser adapted to operate at a lower temperature, a vapor conduit connecting the evaporator with the condenser, a liquid collecting zone connected to said condenser, a liquid conduit connecting said liquid collecting zone with said evaporator and a pump in said liquid conduit, a vapor motor connected to said pump, the input to said motor connected to said evaporator and the exhaust from said motor connected to the condenser, means to sense the liquid level at a selected point in said evaporator, a valve in said vapor conduit responsive to said means.

5. In the apparatus of claim **4** a second sensor positioned at said condenser to sense the condition at a selected point at said condenser, a second valve in series with said first named valve, means to open and close said second valve responsive to the condition sensed by said sensor at said condenser.

6. In the apparatus of claim **5** in which said condenser includes an insulated container for refrigerant, cooling conduits adapted to be in heat exchange relation to refrigerant in said refrigerant container.

7. In the apparatus of claim **6,** an enclosure for said evaporator, a fan positioned in said enclosure, a motor connected to said fan, a vapor conduit connecting said first mentioned vapor conduit to said last named motor, an exhaust vapor connection connected to said last named motor and said condenser.

8. In the apparatus of claim **4,** an enclosure for said evaporator, a second conduit connected to said first mentioned conduit, a second motor connected to said second conduit and said condenser, a fan positioned in said enclosure connected to said second motor, a valve in said second conduit between said evaporator and said motor, a temperature sensor positioned in said enclosure and operatively connected to said last named valve to open and close said valve responsive to the temperature at said last named sensor.

9. In the apparatus of claim **8** in which said condenser includes an insulated container for refrigerant, cooling conduits in said condenser adapted to be in heat exchange relation to refrigerant in said refrigerant container.

10. In the apparatus of claim **8,** said means comprising means to sense the degree of superheat at the selected point in said evaporator, said valve operatively connected to saiid means to open and close as the degree of superheat rises or falls at said selected point.

11. In the apparatus of claim **4,** a second valve connected to the outlet of said evaporator and responsive to the pressure difference between the inlet to and the outlet from said first mentioned valve, a second motor and the outlet of said second valve connected to the input of said second motor, the exhaust of said second motor connected to said condenser.

12. In the apparatus of claim **11** said means comprising means to sense the degree of superheat at the selected point in said evaporator, said first valve operatively connected to said means to open and close as the degree of superheat rises or falls at said selected point.

13. In the apparatus of claim **11,** a third valve connected between said second valve and said second motor, an enclosure for said evaporator, a fan positioned in said enclosure and connected to the second motor, means to sense the temperature at a selected zone in said enclosure, said third valve operatively connected to said last named means to open and close as the temperature at said selected zone falls or rises.

14. In the apparatus of claim **13,** a sensor positioned at said condensor, a fourth valve connected to the evaporator and to said first mentioned valve and means to open and close said fourth valve responsive to the condition sensed by said sensor at said condenser.

15. In the apparatus of claim **11,** in which said condenser includes an insulated container for refrigerant, cooling conduits adapted to be in heat exchange relation to refrigerant in said refrigerant container.

16. In the apparatus of claim **15,** said means comprising means to sense the degree of superheat at the selected point in said evaporator, said first valve operatively connected to said means to open and close as the degree of superheat rises or falls at said selected point.

17. In the apparatus of claim **4** in which said condenser includes an insulated container for refrigerant, cooling conduits in heat exchange relation to said refrigerant in said refrigerant container.

18. In the apparatus of claim **4,** a second motor, a vapor conduit connecting the input of said second motor to said evaporator, and a vapor exhaust connection from said second motor connected to said condenser.

19. In the apparatus of claim **18** in which said condenser includes an insulated container for refrigerant, cooling conduits in said condenser adapted to be in heat exchange relation to refrigerant in said refrigerant container.

20. In the apparatus of claim **4,** said means comprising means to sense the degree of superheat at the selected point in said evaporator, said valve operatively connected to said means to open and close as the degree of superheat rises or falls at said selected point.

21. In the apparatus of claim **20** in which said condenser includes an insulated container for refrigerant,

cooling conduits adapted to be in heat exchange relation to said refrigerant in said refrigerant container.

22. In the apparatus of claim 21, a second motor, a vapor conduit connecting the input to said second motor to said first mentioned vapor line, and a vapor exhaust connection from said second motor connected to said condenser.

23. In the apparatus of claim 22, said evaporator comprising a conduit connected to said first mentioned pump and to said first mentioned vapor conduit, an insulated enclosure for said conduit, a fan mounted for circulation of air over said conduit and in said enclosure, said fan operatively connected to said second motor.

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