

July 7, 1936.

R. V. GRAYSON

2,046,451

CONTROLLED SYSTEM USING SUBLIMATING REFRIGERANT

Filed March 22, 1934

3 Sheets-Sheet 1

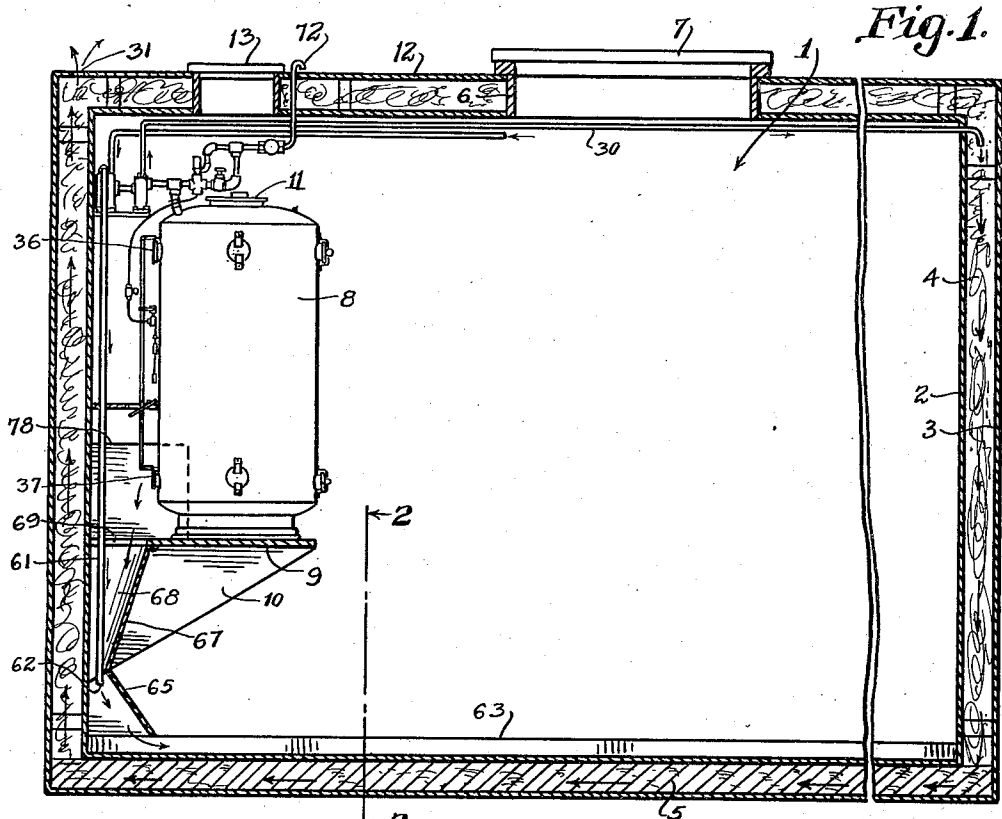


Fig. 2.

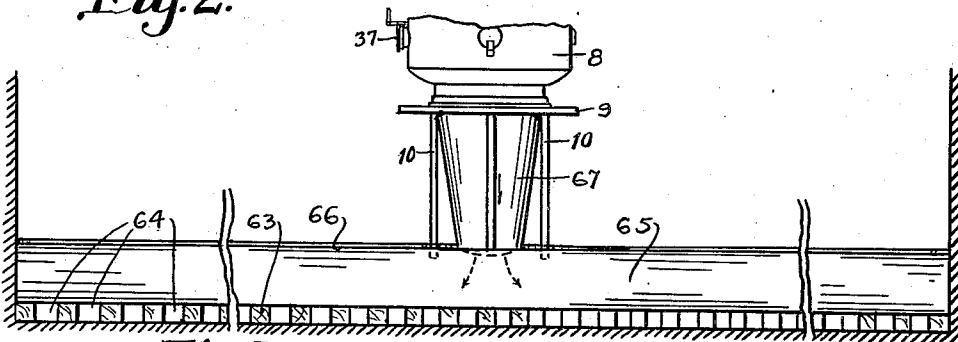


Fig. 3.

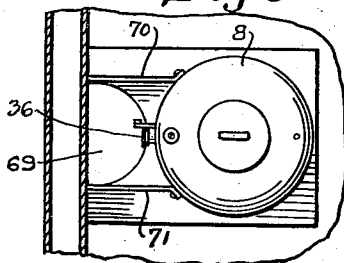
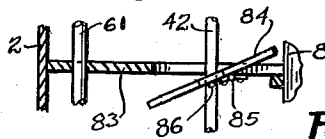


Fig. 15.



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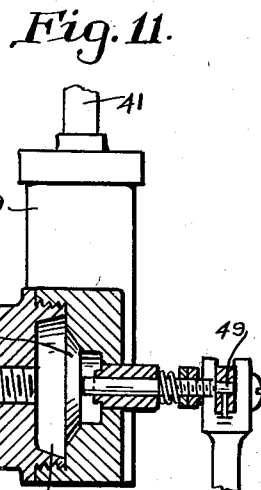
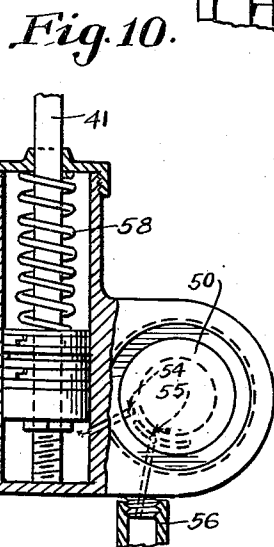
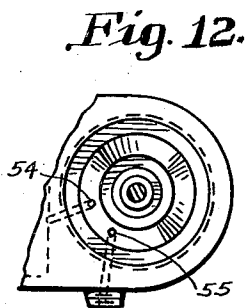
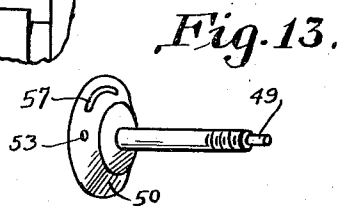
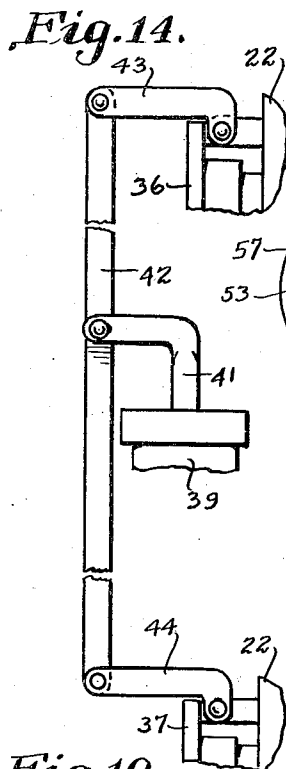
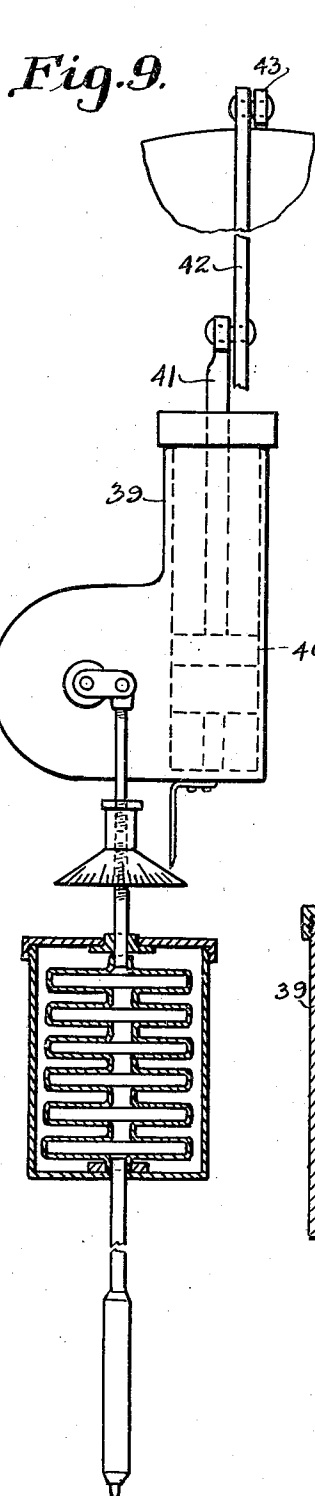
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UNITED STATES PATENT OFFICE

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CONTROLLED SYSTEM USING SUBLIMATING REFRIGERANT

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Application March 22, 1934, Serial No. 716,897

7 Claims. (Cl. 62—91.5)

This invention relates to a refrigeration system in which the vapor pressure of the volatilized refrigerant is employed to effect a positive circulation of the atmosphere of the refrigerated chamber.

One of the objects of the invention is to provide a refrigeration system of the type indicated in which the supplying of fluid pressure of the refrigerant vapor to the circulating means is controlled by storing the pressure while it is below a determined minimum so that the circulating means operates intermittently, the operating cycles taking place only when the fluid pressure exceeds the determined datum. This conserves the vapor pressure for use when the refrigerating demands are great and when the rate of evaporation of the refrigerant is most active, and prevents the pressure being wasted at times when it is being evolved at a rate too feeble to perform any useful air circulating function.

Another object of the invention is the controlling of the rate of evaporation of a solid sublimating refrigerant by confining it under the tension of its own vapor until the refrigerating demands have raised this pressure to a determined value, then releasing the pressure so as to accelerate the rate of evaporation of the refrigerant, in conjunction with an auxiliary control obtained by a body of air thermostatically held in static enveloping relation to the refrigerant when the refrigerating demands are low, and circulated about said refrigerant in circuit with the air of said chamber when the refrigerating demands have risen to a value determined by a temperature of the refrigerator, whereby the rate of evaporation of the refrigerant is augmented.

A further object of the invention is the provision of a double walled refrigerated chamber and a refrigeration system therefor employing a solid sublimating refrigerant adapted in its vaporous state to be circulated between the walls of the refrigerator chamber and the pressure of the evolved vapor being employed to circulate air within the refrigerated chamber.

Still another object of the invention is the provision in a refrigerated chamber of the type described of means constituting in effect a venturi for entraining air from the upper part of said chamber with the air being positively forced into the lower part of said chamber whereby substantially uniform temperature conditions are provided in both the upper and lower regions of said chamber.

Another object of the invention relates to the thermostatically controlled valve for governing the opening and closing of dampers which change the static body of air enveloping the solid refrigerant to a circulatory flow in communication with the body of air in the refrigerated chamber.

Other objects of the invention will appear as the following description of a preferred and practical embodiment thereof proceeds.

In the drawings which accompany and form a part of the following specification and throughout the several figures of which the same characters of reference have been employed to designate identical parts:

Figure 1 is a vertical cross section somewhat diagrammatic through a refrigerated chamber, representing in the present instance the hold of a ship and employing the refrigerating apparatus contemplated by the present invention;

Figure 2 is a section taken along the line 2—2 of Figure 1;

Figure 3 is a fragmentary view partly in section and partly in plan, looking down upon the carbon dioxide evaporator;

Figure 4 is a vertical sectional view through the evaporator and showing also the parts of the refrigeration system thereto appertaining;

Figure 5 is a transverse view partly in plan and partly in cross section of the evaporator shown in Figure 4;

Figure 6 is a detailed view on small scale of the damper actuating mechanism;

Figures 7 and 8 are respectively, a front elevation and a side section through the inspection port closure mechanism;

Figure 9 is a side sectional view through the thermostatic pressure operated damper actuating mechanism;

Figure 10 is a front view partly in section of a portion of the mechanism shown in Figure 9;

Figure 11 is a detail view of part of Figure 10, showing the valve seat;

Figure 12 is a bottom plan view of the valve;

Figure 13 is a plan view of the valve;

Figure 14 is a side elevation showing damper connections; and

Figure 15 is a detail in section of the horizontal damper.

Referring now in detail to the several figures and first adverting to Figures 1, 2, and 3, the numeral 1 represents in general a refrigerated chamber. Although as stated it depicts the hold of a ship, it is not limited to any specific type of refrigerator, but is of general application.

The refrigerated chamber 1 is defined by spaced walls 2 and 3 constituting between them an insulating jacket space 4 which is preferably filled at the side and top with loosely packed granulated or fibrous insulating material. The space 5 between the bottom walls of the refrigerated chamber is preferably filled with a more sturdy type of insulation such as compressed cork board on account of the fact that this portion of the refrigerator must stand the weight of its contents.

A cargo hatch 6 opens through the top walls of the refrigerated chamber, the same being provided with a closure 7 as is customary in the art.

Within the hold is an evaporating tank 8 arranged, for convenience in storing the cargo, as far away from the hatch 6 as is practicable, and being suitably supported as upon the shelf 9 braced by gussets 10. The shelf and gussets are preferably mounted on one of the inner side walls 2 of the hold. The evaporating tank 8 has a cover 11 at the top and in registry with the cover the deck 12 is provided with a hatch 13 through which access may be had for the removal of the cover and for the filling of the evaporating tank 8 with blocks of dry ice.

Referring for awhile to Figures 4 to 7, inclusive, the evaporating tank is seen to consist of an inner shell 14 arranged in spaced relation to an intermediate shell 15, said shells forming between them an air jacket. In order to minimize heat losses through metallic paths, the inner shell is supported within the intermediate shell by upper and lower plates 16 and 17 of minimum mass, and area of contact, either with the inner or outer shell. The upper plates 16 are merely radial members welded with the respective shells. Since the lower plates 17 bear the load they are of somewhat stiffer construction providing seats 18 on which rests the marginal portions of the inner shell, and reinforcing wings 19. The plates 17 are welded to the inner and intermediate shells.

The air jacket between the shells 14 and 15 is in interrupted communication with the atmosphere by upper and lower sleeves 20 and 21 constituting an air inlet and outlet which when open permit circulation of air from the chamber of the hold through the inlet 20, around the air jacket, discharging by way of the outlet 21.

The inner and intermediate shells 14 and 15 are surrounded by an outer shell 22 the space between the intermediate and outer shells being a vacuum insulating chamber the attenuation of which may be renewed at any desired time by the attachment of suitable vacuum pump to the nipple 23. All the openings which intersect the vacuum chamber are of course suitably bushed in a fluid tight manner so as to prevent loss of vacuum. The inner shell is provided with a manhole 24 having a suitable closure 25 in alignment with the cover 11 of the outer shell, which cover and closure are removed when charging dry ice into the inner shell 14.

The intermediate shell 15 rests upon a series of cylindrical supports 26 welded to the inside of the outer shell, but preferably free with respect to the intermediate shell. These supports present contacting edges to the intermediate shell and thus minimize the metallic thermal leakage path through said supports. While they might be made with knife edges, it is preferred on account of the load which they have to bear to

make them cylindrical, the contacting edge being amply supported by lateral metal after the principle of the arch.

It will be understood that while the evaporating tank 8 is here shown as being vertically mounted, it is within the purview of the invention to mount it horizontally if desired, the change in position however necessitating a relative shifting of the charging openings to the uppermost part of the tank and the positioning of the inlets and outlets 20 and 21 so that the inlet is above the outlet in order to promote convective circulation.

A pipe 27 connects with the inner shell 14 and extends through a bushed passage through the other two shells from which point it leads to a turbine 28 which drives a blower 29. The sublimation of the dry ice within the shell 14 creates carbon dioxide vapor under pressure in the upper part of the shell 14 which fluid under pressure traverses the pipe 27 and drives the turbine 28. Referring to Figure 1, it will be observed that the exhaust vapor from the turbine 28 is conducted by way of a pipe 30 through the inner wall 2 of the hold and into the space which is filled with the loosely packed insulation. Here it terminates and the exhaust carbon dioxide percolates downwardly through the loose insulation filling the interstitial spaces on all four sides of the hold and filling the insulation between the two top walls, the upper of which forms the deck 12. An exit for the spent carbon dioxide is provided in the deck at the vent 31. It will be understood that on account of its weight, the cold carbon dioxide within the insulation walls will be constantly renewed displacing the warmer carbon dioxide which escapes through the vent 31.

In the interest of heat conservation, the pipe 30 carrying the exhaust carbon dioxide from the turbine passes for substantially its full length through the upper part of the refrigerated chamber where the rate of heat exchange is at its maximum.

Referring now to Figure 4, it will be noted that the pipe 27 is provided at a point intermediate the evaporator tank 8 and the turbine 28 with a pressure actuated valve 32 so set that it remains closed until a determined pressure has developed in the tank 8 and the adjacent part of the pipe 27. While the valve 32 is thus closed, the turbine 28 is inactive. When the pressure of the vapor of the refrigerant within the shell 14 exceeds the critical pressure at which the valve 32 opens, the latter then admits the fluid under pressure to the turbine 28, driving the same and operating the blower. Thus the action of the turbine and the blower is intermittent. When the valve 32 is closed the danger of excess pressure being build up in the shell 14 is avoided by the provision of a safety valve 33 in a lateral branch of the pipe 27 and which safety valve when open discharges to atmosphere by way of a pipe 34. A hand operated blow-off valve 35 is also provided, by-passing the safety valve 33 and adapted to be alternatively used.

The inlet and outer ports are normally closed by dampers 36 and 37 so that there is no circulation of air in the air jacket. This is the condition of the system when the temperature within the refrigerated chamber is low. The dampers are controlled by a thermostatically controlled motor 38 comprising a cylinder 39 in which a piston 40 reciprocates, the piston being

connected to an operating rod 41 suitably attached to a link 42 pivotally connected to bell cranks 43 and 44 by means of which the dampers which are hingedly mounted are opened and closed.

A transverse partition 83 is formed intermediate the inlet and outlet ports, separating the upper part of the refrigerated chamber adjacent the inlet ports from the lower part of the refrigerated chamber adjacent the outer port. The partition 83 has a damper 84 hinged as at 85 and connected to the mechanism which actuates the dampers 36 and 37 as by a pin 86 on the rod 42, acting against the underside of the damper adjacent a slot through which the rod 42 passes so that the damper 84 closes when the said ports are opened, and vice versa. Thus, circulation of the air of the refrigerated chamber from the upper part of the refrigerated chamber to the lower part is diverted through the air jacket when the damper 83 is closed and permitted to descend through said damper when the air jacket is cut off.

The thermostatic element may be of any desired construction, but in the present embodiment of the invention it includes a siphon 45 connected by a suitable tube 46 with a thermal bulb 47 suitably situated within the refrigerated chamber. The siphon actuates a rod 48 which oscillates the shaft 49 of a valve 50. A tube 51 is tapped into the vapor pressure pipe 27 and leads to a chamber 52 in controlled communication by means of the valve 50 with the cylinder 39 on the lower side of the piston 40.

The valve while being oscillatory in function is of poppet construction and is maintained against its seat by the pressure in the chamber 52. The head of the valve has a port 53 opening in the seating surface of said valve and in one position of the valve communicating with a port 54 in the valve seat which communicates with the cylinder 39. In another position of the valve, the port 53 is out of communication with the port 54 and closed by the imperforate portion of the valve seat. An exhaust port 55 opens in the valve seat and leads to atmosphere by a suitable conduit 56. The valve is provided on its seating surface with an arcuate groove 57 adapted in a certain position of said valve to bridge the ports 54 and 55 and thereby to vent the lower part of the cylinder 39 permitting return of the piston 40 under the urge of the spring 58. The cylinder space above the piston is relieved of air through a bleed port 59.

The operation of the valve 50 is such that normally when the temperature of the hold is low, the siphon remains contracted and the valve oscillated to a position in which the port 53 is closed. Fluid pressure from the vapor of the refrigerant is always present in the chamber 52 but in the closed position of the valve, it is excluded from the piston 40. In this position of the piston, the link 42 maintains the dampers closed and the air within the air jacket is in static condition. It assumes the temperature of the refrigerant and due to the vacuum jacket which surrounds the air jacket the refrigerant is substantially unaffected by the temperature of the refrigerated chamber.

As the temperature of the hold rises, the siphon expands oscillating the valve 50 until the port 53 comes into registry with the port 54. Pressure from the chamber 52 passes into the cylinder 39 raising the piston 40 and reciprocating the link 42 so as to open the dampers 36 and

37. The air in the air jacket then begins to circulate the cold air descending and discharging from the outlet 21 while warmer air from the refrigerated chamber is inducted into the inlet 20. The circulating air has a profound effect in increasing the rate of sublimation of the dry ice raising the pressure in the upper part of the inner shell 14. The air in the refrigerated chamber is thus cooled by being circulated in the heat exchanging relation to the refrigerant. When the pressure within the shell 14 has attained a predetermined value the valve 32 opens and the accumulated fluid pressure operates the turbine 28 driving the blower 29. In a manner already set forth, the refrigerant vapor exhausting from the turbine through the pipe 30 fills the interstices in the insulating material which occupies the space within the double walls of the sides and tops of the refrigerated chamber.

The blower 29 has an inlet conduit 60 opening near the top of the chamber of the hold drawing warm air from said chamber and discharging it through the eduction pipe 61 at a point 62 adjacent the bottom of the chamber. Means for equalizing the circulation of the air are provided comprising a system of dunnage or spaced beams 63 arranged in parallel relation along the floor and defining between them passages 64. The cargo which is to be refrigerated rests upon the dunnage being packed in such a way as to leave interstices and spaces between the individual parcels of cargo to permit the thorough circulation of air upwardly between said parcels. At one end of the hold, preferably beneath the evaporator tank 8, means such as a board forming a wall 65 extends across the ends of the beams 63 forming a transverse conduit communicating with the passages 64. For the major portion of its length this conduit has a cover 66 excepting where it is joined by the walls 67 of a downwardly convergent duct 68 adjacent the lower end of which the pipe 61 terminates. The upper ends of the walls 67 meet the edges of an opening 69 formed in the rear portion of the shelf. The duct 68 forms a venturi at the lower and constricted end of which the eduction pipe 61 terminates, and when the inlet and outer ports are open said venturi, through the entraining action of the discharge pipe 61, acts to boost the thermo-syphonic circulation of air through said jacket. Lateral partitions 70 and 71 extend upwardly from the rear portion of the shelf to a height above the outlet port 21.

Air circulation is as follows: Warm air is drawn in by the blower through the pipe 60 and is discharged by the pipe 61 into the conduit 62 at the mouth of the venturi. Here it mixes with cold air descending from the outlet port 21 into the duct 68 and which air is entrained through the velocity of the warm air discharging from the pipe 62. The relatively warm and relatively cold airs are thus mixed at the mouth of the venturi and pass laterally through the conduit 62 and downwardly into the passages 64 and upward through the open faces of said passages against and between the various parcels which constitute the refrigerated cargo. The air in the intermediate part of the refrigerated chamber may pass freely to the rear of the evaporator tank 8 and downwardly, mixing with the cold air and being drawn through the influence of the venturi. The air in the refrigerated chamber is thus so thoroughly mixed that in a test appara-

tus, there was a temperature differential of not more than two degrees between the top and bottom of the hold.

When the pressure of the vapor of the refrigerant has decreased below the value determined by the valve 32, the latter closes, the turbine stops, and the blower ceases action. The thermostat which controls the dampers may not immediately close however so that circulation of the cold air at a reduced rate continues for some time. Eventually, the temperature of the refrigerated chamber may decrease to such a point that the thermostatic valve will close permitting the dampers to re-seat, cutting off the air circulation. More often, perhaps, the pressure within the shell 14 will have accumulated to the point at which the turbine and blower will be re-started. Since it is sometimes undesirable particularly in a ship installation to have carbon dioxide accumulate in the lower part of the hold, the vent from the relief valve 33 or the hand valve 35 may terminate above decks as shown at 72 in Figure 1.

For purpose of inspection, the evaporator tank is provided at appropriate points with removable plugs 73 slipping into bushed sight or hand holes 74. The plugs 73 may be made of any desirable construction, but are here shown as comprising disks 75 and 76 of insulating material, suitably spaced apart by a spacer 77 so as to minimize thermal leakage. A bolt runs through the disks and terminates in an operating handle 78. The outer disk is faced with a suitable cover 79 of larger diameter than said disks and adapted to rest on the outer ends of the bushing. For holding the plugs tightly in place, lugs 80 and 81 are secured to the outer shell 22, and the covers 79 are provided with cam elevations 82 adapted to tighten under the lugs 80 when the cover is slightly rotated.

While I have in the above description disclosed what I believe to be a preferred and practical embodiment of my invention, it is to be understood that the specific construction as disclosed is merely by way of example and not to be construed as limiting the scope of the invention as defined in the appended claims.

What I claim is:

1. Refrigeration system employing a sublimating refrigerant, comprising in combination, means forming a refrigerated chamber, an evaporator tank for receiving solid refrigerant, an air jacket surrounding said tank, means for normally insulating said evaporator from the air in the refrigerated chamber, means responsive to the temperature of the refrigerated chamber for normally maintaining the air in said jacket static, but permitting the circulation of the air of said refrigerated chamber through said jacket upon a predetermined rise of temperature in said refrigerated chamber, a turbine, a conduit placing said turbine in communication with said evaporator, a pressure actuated valve in said conduit opening responsive to the attainment of a pre-determined pressure value in said evaporator for supplying the vaporized refrigerant under pressure to said turbine, a blower driven by said turbine, said blower having an air inlet opening in the upper portion of said refrigerated chamber and an air outlet opening in the lower part of said chamber.

2. Refrigeration system employing a sublimating refrigerant, comprising in combination, means forming a refrigerated chamber, an evaporator tank for receiving solid refrigerant,

an air jacket surrounding said tank, means for normally insulating said evaporator from the air in the refrigerated chamber, means responsive to the temperature of the refrigerated chamber for normally maintaining the air in said jacket static, but permitting the circulation of the air of said refrigerated chamber through said jacket upon a predetermined rise of temperature in said refrigerated chamber, a turbine, a conduit placing said turbine in communication with said evaporator, a pressure actuated valve in said conduit opening responsive to the attainment of a pre-determined pressure value in said evaporator for supplying the vaporized refrigerant under pressure to said turbine, a blower driven by said turbine, said blower having an air inlet opening in the upper portion of said refrigerated chamber and an air outlet opening in the lower part of said chamber, means forming a venturi in said refrigerated chamber into which the outlet of the blower discharges whereby said venturi boosts the circulation of air of the refrigerated chamber through the jacket of said evaporator.

3. Refrigeration system employing a sublimating refrigerant, comprising in combination means forming a refrigerated chamber, an evaporator tank for receiving solid refrigerant, an air jacket surrounding said tank, means normally insulating said evaporator from the air in said refrigerated chamber, means responsive to the temperature of the refrigerated chamber for normally maintaining the air in said jacket static, but permitting the circulation of the air of said refrigerated chamber through said jacket upon a pre-determined rise in the temperature of said refrigerated chamber, said temperature responsive means comprising synchronously opened and closed dampers controlling upper and lower ports communicating with the jacket of said evaporator, a conduit connecting said turbine with said evaporator, a pressure responsive valve in said conduit opening only to a pre-determined pressure value in said evaporator for admitting motive fluid in the form of gaseous refrigerant to said turbine, a blower driven by said turbine having an air inlet opening in the upper portion of said refrigerated chamber, means forming a venturi in the lower part of said refrigerated chamber, the outlet of said blower opening adjacent the neck of said venturi whereby a downward current of air is entrained in said venturi, boosting the thermo-syphonic circulation of air through the jacket of said evaporator, a damper arranged in said refrigerated chamber intermediate said upper and lower ports and operatively connected relative to the dampers which controls said ports so as to close when said dampers are open, and vice versa, said dampers separating the upper from the lower part of said refrigerated chamber when closed compelling a circulation of the air of said chamber through the jacket of said evaporator and when open permitting circulation of air from the upper to the lower portions of said refrigerated chamber.

4. Refrigeration system employing a sublimating refrigerant, comprising in combination, means forming a double walled refrigerated chamber, an evaporator tank for receiving solid refrigerant, an air jacket surrounding said tank, means for normally insulating said evaporator from the air in said refrigerated chamber, means responsive to the temperature of said refrigerated chamber for maintaining the air in said

jacket static, but permitting the circulation of the air of said refrigerated chamber through said jacket upon a pre-determined rise in the temperature of said refrigerated chamber, a turbine, a conduit connecting said turbine to said refrigerated chamber, a pressure responsive valve in said conduit opening upon the attainment of a determined high gaseous pressure in said evaporator for admitting motive fluid in the form of gaseous refrigerant to said turbine, the outlet of said turbine being arranged to discharge the gaseous refrigerant between the double walls of said refrigerated chamber, a blower having an inlet opening in the upper part of said refrigerated chamber, means forming a venturi at the lower part of said chamber, said blower having an outlet discharging into the neck of said venturi thereby inducing circulation of air through said refrigerated chamber and boosting the thermo-syphonic circulation of air through the jacket of said evaporator.

5. Refrigeration system employing a sublimating refrigerant, comprising in combination, means forming a refrigerated chamber, an evaporator tank for receiving solid refrigerant, an air jacket surrounding said tank, a vacuum jacket surrounding said air jacket for normally insulating said evaporator from the air in said refrigerated chamber, upper and lower ports establishing communication between the refrigerated chamber and said air jacket, dampers responsive to the temperature of the refrigerated chamber, normally closed, for maintaining the air in said jacket static, but opening upon a predetermined rise in the temperature of said refrigerated chamber for permitting circulation of the air of said chamber through said jacket, and a blower creating a circulation of air in said refrigerated chamber, and functioning through the intermediary of a venturi to boost the thermo-syphonic circulation of air through the jacket of said evaporator.

6. Refrigeration system employing a sublimating refrigerant comprising in combination, a refrigerated chamber, an evaporator for receiving solid refrigerant, and means for conserving said refrigerant comprising a jacket surrounding the evaporator having upper and lower air inlet and outlet ports communicating with the refrigerated chamber, dampers controlling said ports, means connecting said dampers, and means responsive to temperature changes in said refrigerated chamber for closing the dampers when the refrigerating demands are small, but opening said dampers permitting circulation of air from the refrigerated chamber through said jacket when the refrigerating demands are large, comprising a fluid pressure actuated motor operably related to said connecting means, a conduit establishing communication between said evaporator and motor, a valve controlling said conduit and a thermostat actuating said valve.

7. Refrigeration system employing a sublimating refrigerant, comprising in combination, means forming a refrigerated chamber, an evaporator tank for receiving solid refrigerant, an air jacket surrounding said tank, means for normally insulating said evaporator from the air in the refrigerated chamber, and means responsive to the temperature of the refrigerated chamber for controlling the circulation of air through said jacket normally maintaining the air in said jacket static, but permitting the circulation of the air of said refrigerated chamber through said jacket upon a pre-determined temperature rise in said refrigerated chamber, the means for controlling the circulation of air through said jacket comprising dampers synchronously controlled, closing upper and lower ports in said jacket.

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