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REFRIGERATION SYSTEM

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Fig. 1.

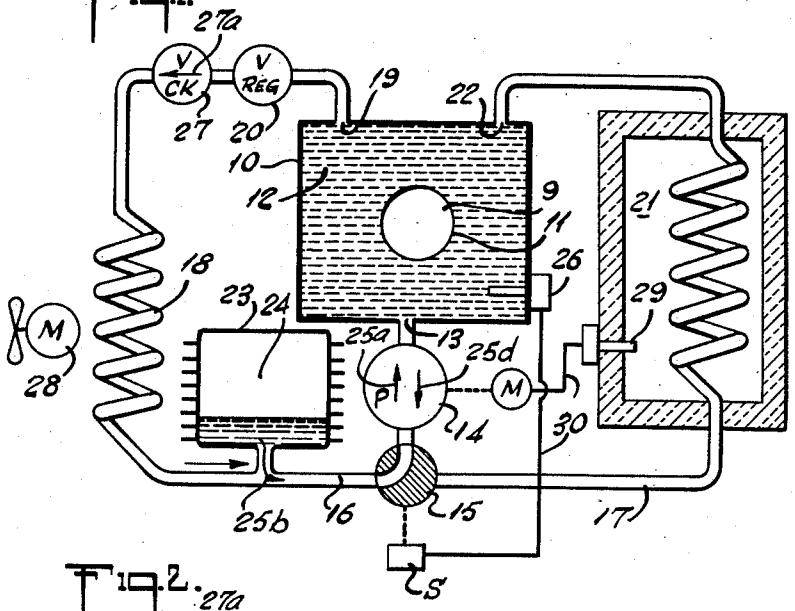


Fig. 2.

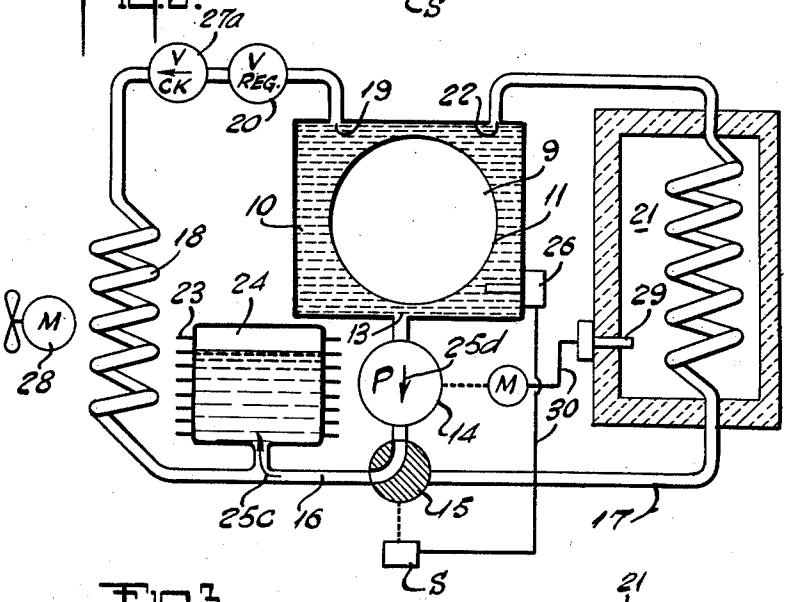
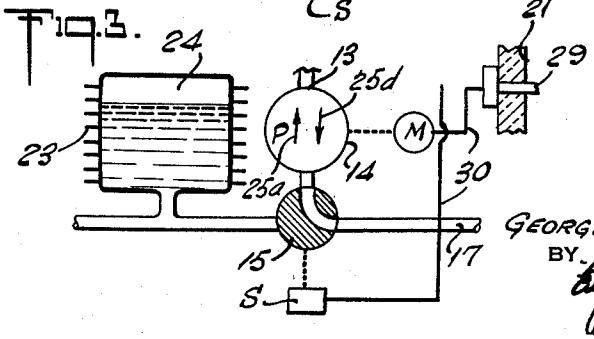


Fig. 3.



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REFRIGERATION SYSTEM

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10 Claims. (Cl. 62—174)

This invention relates to mechanical refrigeration apparatus and a method in which the various phases of the refrigeration cycle take place in one device.

In the usual vapor compression type of refrigeration apparatus, the refrigerant is caused to circulate progressively from an upper temperature and pressure region of the cycle to a lower temperature and pressure region thereof through various segregated and distinct devices to accomplish the expansion of the condensed refrigerant.

It is the principal object of this invention to provide a method and apparatus in the form of mechanical refrigeration in which the various phases of the refrigeration cycle take place in one device.

It is a further object of the instant invention to provide a refrigeration tank in which there is suspended a completely enclosed expandable and contractable vessel containing a suitable refrigerant material adapted to be liquefied upon the application of high pressure and below a certain temperature. During one phase of the cycle of operation, a convective energy carrier in the form of a flowable fluid is circulated through the refrigeration tank by a pump whereby heat is transferred from the refrigerant to the flowable fluid as the latter compresses the contractable vessel containing the refrigerant. During the next phase of operation, some of the flowable fluid is pumped from the tank into a reservoir. As this action empties the tank, the refrigerant vessel expands, which expansion lowers the temperature of the convective carrier fluid remaining in the tank; during the next phase of operation, the refrigeration tank is interconnected with the region to be cooled. The convective fluid remaining in the refrigeration tank is then allowed to circulate through the region to be cooled wherein the circulating fluid is at a lower temperature by reason of expansion of the refrigerant vessel containing the refrigerant gas.

It is a further object of the invention to employ an expandable and contractable but fully enclosed and pressure responsive vessel containing the refrigerant. The refrigerant is maintained enclosed in the vessel for the entire cycle of operation. This provides the advantage of avoiding loss of refrigerant which loss is otherwise experienced while such refrigerant is circulated as in prior art systems, and provides the further advantage of eliminating the precautions observed in prior art refrigerant circulating systems for preventing leakage, particularly, where a dangerous refrigerant is employed. Consequently, any suitable refrigerant may be employed in the practice of the invention.

It is a further object of the invention wherein it allows the use of any suitable flowable convective carrier, such as water, brine or other flowable material in the practice of the invention.

Further objects and advantages will become apparent from the following description of the invention taken in conjunction with the figures, in which:

Figs. 1 through 3 illustrate schematically the various

phases of the cycle of operation in accordance with the practice of the instant invention.

Reference is now made to the figures wherein **10** depicts a rigid pressure type tank containing an expandable and contractable vessel **11** of suitable material. Vessel **11** is fully enclosed and is immersed and supported within a fluid **12**. Fluid **12** is a flowable convective energy carrier of any suitable material. Vessel **11** contains an expandable and contractable refrigerant material **9** such as a suitable gas which upon contraction, by reason of pressure applied to the outer surface of vessel **11**, will convert at some predetermined pressure and temperature into a liquefied state. Tank **10** has a port **13** coupled to a reversible pump **14**. Pump **14** is coupled to a two-way valve **15**. Pump **14** is operated by a reversible motor M. Motor M and valve **15** are regulated by respective control circuits to be described hereinafter. Depending upon its position, valve **15** is adapted to interconnect tank **10** alternately with one or the other of two conduits **16** and **17**. Conduit **16** has one branch leading to a fluid supply or reservoir **23** and a return branch **18** connected to a tank outlet port **19** via a regulating valve **20** and a check valve **27**. Check valve **27** will permit fluid to flow from tank **10** in the direction of arrow **27***a* when branch **18** is opened by regulating valve **20** in response to a predetermined high pressure in tank **10**. Conduit **17** passes through a region **21** to be cooled and returns to tank **10** via a port **22**.

The cycle of operation will be described starting with the condensing or compression phase thereof. It will be understood that reservoir **23** is substantially full with fluid **12** and that there is a substantial pressure head existing in space **24** between the surface level of fluid **12** and the ceiling of reservoir **23** at the start of the condensing phase. In addition, conduit **16** and branch **18** are substantially full with fluid **12**, regulating valve **20** is closed to prevent porting of fluid **12** out of tank **10**, vessel **11** is substantially fully expanded and valve **15** is oriented as shown in Fig. 1 at the start of the condensing phase. With valve **15** turned as shown in Fig. 1, reservoir **23** is interconnected with tank **10**; whereas motor M has been adapted to pump fluid **12** in the direction of arrow **25***a*.

Fluid **12** is pumped from reservoir **23** through conduit **16** in the direction of arrow **25***b* and into tank **10** via port **13** and consequently builds up pressure in tank **10** acting upon vessel **11**. The flow of fluid **12** into tank **10** is also aided by the pressure head previously developed at region **24** in reservoir **23**. The foregoing action contracts vessel **11** and thus compresses the refrigerant gas **9** in said vessel. Compression of gas **9** in vessel **11** results in generation of heat which is transmitted to fluid **12** in tank **10**. The pressure build up in tank **10** will increase until regulating valve **20** opens at a predetermined pressure to permit flow of some fluid **12** through the low pressure side of the system and thus through check valve **27**, branch **18**, conduit **16** and back into tank **10** in the direction of arrows **27***a* and **25***a*. Accordingly, upon opening of regulating valve **20**, fluid **12** circulates about the system via branch **18**. The amount of flow of fluid **12** from tank **10** via outlet port **19** is less than the amount of fluid flow into tank **10** via port **13**. The differential in quantity of fluid **12** is supplied from reservoir **23** which is gradually depleted. The foregoing action increases the pressure build up in tank **10** and thus further contracts vessel **11** and is obtained by continued operation of pump **14**. Compression of gas **9** in vessel **11** results in a generation of heat which is transmitted to the circulating fluid **12**. As fluid **12** circulates, it is cooled by cooling means such as a fan **28**. Fan **28** is also adjusted to cool the contents of reservoir **23**. Continued application of pressure by pump **14** and

cooling by fan 28 results in gas 9 converting into a liquid state at a predetermined pressure and temperature. Even though a state of relatively constant pressure is now reached in tank 10, circulation of fluid 12 around tank 10 and branch 18 is continued by pump 14 until the system is triggered or commanded to start the expansion phase of the cycle. Fig. 1 depicts vessel 11 in its contracted state.

When the temperature in region 21 finally rises above a predetermined value, for example 50° F., a thermostat 29 responsive to the temperature therein will operate to change direction of motor rotation and thus the direction of pump operation to effect flow of fluid 12 in the direction of arrow 25*d*. Activation of thermostat 29 at such preselected and relatively high temperature in area 21 initiates the expansion phase of the cycle of operation which is depicted in Fig. 2. During this phase of operation, fluid 12 is pumped quickly from tank 10 via port 13 and conduit 16 in the direction of arrow 25*c* (Fig. 2) back into reservoir 23. Pumping action is aided by the high pressure existing in tank 10 and the low pressure existing in reservoir 23. Check valve 27 prevents flow of fluid 12 against arrow 27*a* and into tank 10. As fluid 12 returns to reservoir 23, a pressure head is developed at 24 to be used as an aide in emptying reservoir 23 during the first phase of cycle of operation as noted hereinbefore. Vessel 11 upon emptying of tank 10 now expands, which expansion causes transfer of heat from fluid 12 remaining in tank 10 to refrigerant 9 in the expanding vessel 11. The refrigerant ultimately reconverts to a gaseous state.

The temperature of fluid 12 remaining in tank continues to cool by reason of the foregoing action. The drop in fluid temperature in tank 10 is sensed by a thermostat 26. At some predetermined low value of temperature in tank 10, thermostat 26 is activated to operate a reversing solenoid S in the control circuit to turn valve 15 so as to interconnect tank 10 with conduit 17 as depicted in Fig. 3, which figure illustrates the cooling phase of cycle of operation.

Fluid 12 remaining in tank 10 is now circulated through region 21 by pump 14 in the direction of arrow 25*d*. The temperature of the circulating fluid in tank 10 is very low because of the preceding expansion phase and causes area 21 to cool. Consequently, the temperature of area 21 drops. When thermostat 29 senses a drop in temperature in region 21 of some desired and predetermined value, it causes motor rotation to reverse. Circulation of the cooled refrigerant 12 continues through region 21 but now in the direction of arrow 25*a*. The last-mentioned reversal of motor M and thus reversal of pump operation serves to prepare the system for the compression phase next to follow. As fluid 12 continues to circulate and cool area 21, the temperature in tank 10 rises. The duration of the cooling phase of the cycle continues until the temperature of the circulating fluid 12 reaches a preselected value in tank 10 which is sensed by thermostat 26. This causes thermostat 26 to operate the reversing mechanism S so that valve 15 turns back to the position shown in Fig. 1 and thus starts the system for the first phase of the operation.

The refrigerant system shown herein may be operated by manual control or automatic means. If automatic regulation is employed a conventional regulating circuit may be used. Consequently, the circuit depicted herein is shown schematically. The control circuit includes motor M and a conventional reversing relay responsive to thermostat switch 29 and incorporated in motor M for controlling the direction of motor rotation and thus the direction of pump operation. Motor M is mechanically linked to pump 14 as shown by broken line to effect pump operation. A reversing solenoid S is respfonsive to operation of thermostat switch 26 and is mechanically linked to valve 15 to regulate the position of same. The foregoing units are connected to respective switches 26, 29 by wires 30.

Automatic operation will now be summarized. As noted hereinbefore, during the cooling phase, fluid 12 circulates through tank 10 and area 21. At the start of this phase, the temperature in tank 10 will be relatively low, for example in the order of 38° F. or 40° F., whereas the temperature of area 21 normally will be above a preselected value such as 50° F. Actually, the rise of temperature in area 21 above the preselected value of 50° F. lead to the cooling phase by triggering the system into the immediately preceding expansion phase. During the cooling phase, the temperature of area 21 drops as the temperature in tank 10 rises. When the temperature of area 21 drops below a second preselected value, for example 47° F., thermostat 29 causes pump 14 to reverse to effect the flow of circulating fluid 12 in the direction of arrow 25*a*. This is desirable in order to prepare the system for the subsequent condensing phase of operation next to occur. However, the cooling phase continues with flow as depicted by arrow 25*a* until the temperature in tank 10 rises to a preselected value, for example 43° F. or even 45° F., but preferably after motor M has been reversed by thermostat 29 to effect flow depicted by arrow 25*a*. When thermostat 26 senses the predetermined and relatively higher temperature in tank 10, the cooling phase ceases and valve 15 is reversed to couple with branch 16 to initiate the compression phase. As noted hereinbefore, vessel 11 is fully expanded, reservoir 23 is substantially full of fluid 12 at this time.

The compression phase follows the pattern as described hereinbefore. During this phase, valve 20 will ultimately open to allow circulation of fluid 12 through branch 18 and tank 10. The condensing phase and thus circulation of fluid 12 will continue in this manner until a command signal is provided by thermostat 29. This will occur when the temperature of area 21 finally rises above a predetermined value, such as 50° F., and thus triggers pump reversal to effect fluid flow in the direction of arrow 25*d*. Once this comes about, the expansion phase commences and continues until thermostat 26 senses the low temperature of 38° F. which causes valve 15 to turn and couple to conduit 17 to initiate the cooling phase.

When the equipment is initially turned on, the temperature in area 21 normally will be higher than the 50° value, consequently, it is desirable that thermostat 29 is manually interrupted or otherwise interrupted by the starting switch employed to allow one compression phase of a cycle to be completed.

It should be understood that the values of predetermined and preselected temperatures set forth herein are merely illustrative examples to describe system operation.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. Refrigeration apparatus comprising, means containing a flowable convective carrier, expandable and contactable means containing a refrigerant medium and being immersed and suspended in said carrier, means for circulating said carrier through said first-mentioned means and into alternate conduits externally of said first-mentioned means, a first of said conduits including a branch for returning said carrier to said first-mentioned means, the second of said conduits being operatively associated with a region to be cooled, means for regulating circulation of said carrier through said first-mentioned means and said alternate external conduits wherein, said apparatus undergoing condensing phase of operation as said

regulating means causes said carrier to circulate through said first conduit and through said first-mentioned means at a differential amount to effect increasing pressure on said expandable and contractable means so as to contract same, and means for checking circulation of said carrier into said first-mentioned means as said carrier ports therefrom and into said first conduit during an expansion phase of operation, said regulating means causing said carrier to circulate through said first-mentioned means and said second conduit during the cooling phase of operation.

2. Apparatus as defined in claim 1 wherein said first-mentioned means comprising, a pressure type tank having first and second ports, said expandable and contractable means being a vessel in said tank, at least one of said conduits extending externally of said tank and communicating with said ports and being adapted for circulating said flowable carrier externally of said tank and back into said tank.

3. Apparatus as defined in claim 2 wherein, said tank having a third port, the other of said conduits communicating with said third port and also with said first port, said first conduit including a storage reservoir for said flowable carrier.

4. Refrigeration apparatus comprising, a tank containing a flowable convective carrier, an expandable and contractable vessel containing a refrigerant medium and being immersed and suspended in said carrier, means for circulating said carrier through said tank and into alternate conduits externally of said tank, one of said conduits including a branch for returning said carrier to said tank and the second of said conduits being operatively associated with a region to be cooled, means for regulating circulation of said carrier through said tank and said alternate external conduits wherein, said apparatus undergoing condensing phase of operation as said regulating means causes said carrier to circulate through said first conduit and through said tank at a differential amount to cause an increasing pressure on said vessel to contract same, and means for checking circulation of said carrier into said tank as said carrier ports therefrom and into said first conduit while said vessel is allowed to expand, said regulating means causing said carrier to circulate through said tank and said second conduit during the cooling phase of operation.

5. Apparatus as defined in claim 4, said tank having first, second and third ports, said regulating means including a two-way valve communicating with said first port, said first and second conduits communicating with said second and third ports, respectively, and both communicating with said two-way valve, actuation of said valve from one to another of two positions allows said flowable carrier to flow from said tank into a respective conduit.

6. Apparatus as defined in claim 5 wherein said checking means comprising, a valve at said second port communicating with said first conduit and adapted to allow circulation of carrier through said first conduit and said tank during the condensing phase of the cycle for contracting said vessel and checking flow of said carrier into said tank during the expansion phase of the cycle to permit expansion of said vessel, said two-way valve being actuated to allow porting of said carrier from said tank during both the condensing and expansion phases of the cycle.

7. Apparatus as defined in claim 6 wherein said tank having a valve responsive to the pressure of carrier in said tank and adapted to allow the flow of carrier therefrom when the pressure therein rises to a predetermined amount.

8. Refrigeration apparatus comprising, a tank containing a flowable convective carrier, an expandable and contractable vessel containing a refrigerant medium and being immersed and suspended in said carrier, means for circulating said carrier through said tank and into alternate conduits externally of said tank, one of said conduits including a branch for returning said carrier to said tank and the second of said conduits being operatively associated with a region to be cooled, means including a two-way valve for regulating circulation of said carrier through said tank and said alternate external conduits wherein, said apparatus undergoing a condensing phase of operation as said regulating means causes said carrier to circulate through said first conduit and through said tank at a differential amount to cause an increasing pressure on said vessel to contract same, and means for checking circulation of said carrier into said tank as said carrier ports therefrom and into said first conduit while said vessel is allowed to expand during a succeeding phase of operation, said regulating means causing said carrier to circulate through said tank and said second conduit during the cooling phase of operation.

9. Apparatus as defined in claim 8 further comprising, a reservoir for storing an overflow of flowable carrier and communicating with said first conduit, and cooling means operatively associated with said first conduit.

10. Apparatus as defined in claim 8 further comprising, temperature responsive means in said tank for activating operation of said two-way valve for interconnecting said tank with said second conduit for the cooling phase of the cycle, and for interconnecting said tank with said first conduit during the condensing and expansion phases of said cycle.

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