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REFRIGERATION SYSTEM

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FIG. 1.

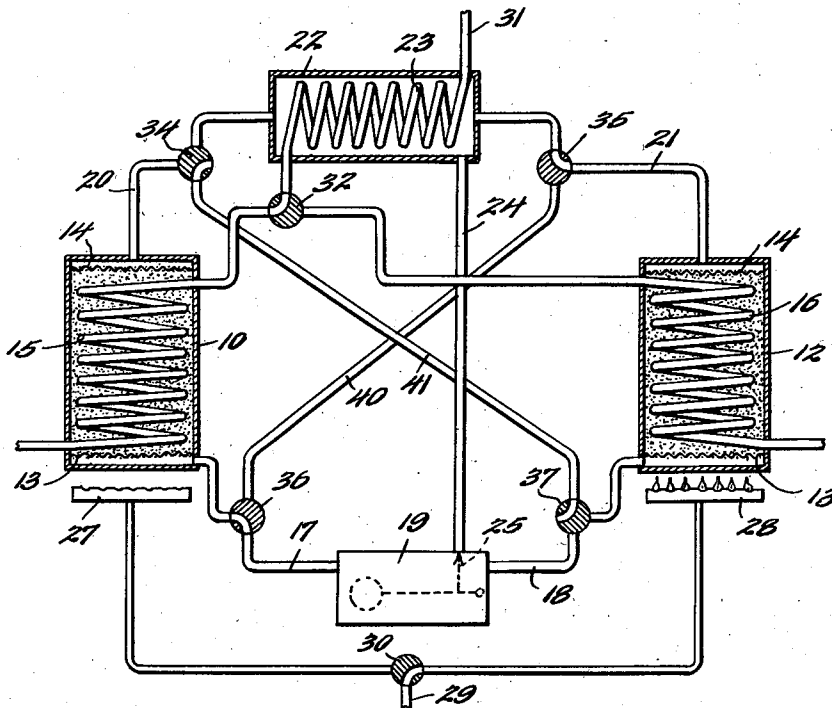
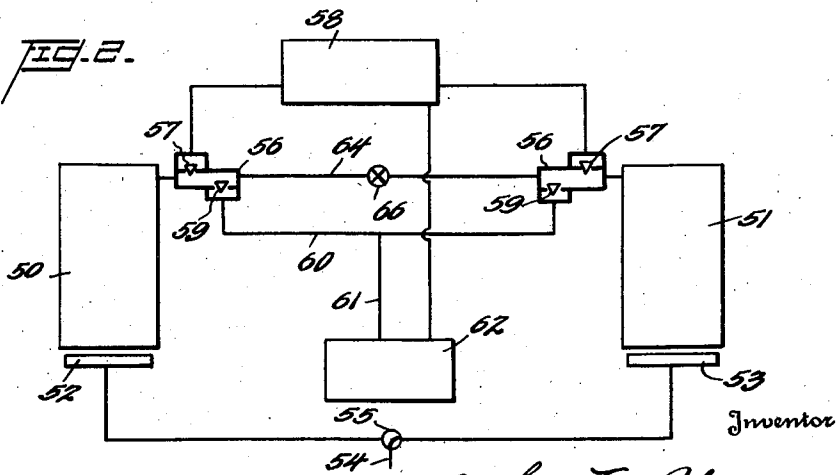


FIG. 2.



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REFRIGERATION SYSTEM

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12 Claims. (Cl. 62-118)

This invention relates to refrigeration processes and apparatus, and more particularly to adsorption or absorption refrigeration, and especially to a process and apparatus for improving the efficiency of such refrigeration.

It is the general object of the present invention to provide novel and improved refrigeration processes and apparatus.

An important feature of the present invention resides in the provision of an improved refrigeration process and apparatus for carrying out the same wherein means is provided for equalizing the pressures in an adsorber which has just been revived and one which has been at least partially charged with refrigerant by having been connected to the evaporator.

Another important feature of the invention resides in the provision, in a cyclically operating adsorption refrigeration system using a plurality of adsorbers, of compensation for the differences in pressure and temperature existing between adsorbers just removed respectively from the high and low sides of the system.

In the apparatus, the particular feature of the invention resides in a connection or connections between adsorbers, each connection being provided with a valve adapted to be opened for a short time prior to the shifting of adsorbers in the cycle, to connect two adsorbers, one at the highest pressure and the other at the lowest pressure in the system, whereby the pressures can be brought into agreement.

Other and further features and objects of the invention will be more apparent to those skilled in the art upon a consideration of the accompanying drawing and following specification, wherein are disclosed several exemplary embodiments of the invention, with the understanding that such changes and variations may be made therein as fall within the scope of the appended claims without departing from the spirit of the invention.

In said drawing,

Figure 1 is a diagrammatic representation of refrigeration apparatus for carrying out the process of the present invention; and

Figure 2 is a schematic and diagrammatic representation of a modified form of apparatus for carrying out the process.

The present invention contemplates improvements in that type of refrigeration apparatus wherein an adsorbent, absorbent, or material having both adsorbent and absorbent properties, or impregnated adsorbents or absorbents where action may be partly chemical, is used to

adsorb the vapor from the liquid refrigerant in an evaporator to cause cooling of the same. It relates particularly to that type of cyclically operating refrigeration apparatus in which a plurality of adsorbers are provided which are capable of being connected in turn to the evaporator so that the evaporator is cooled continuously. In such apparatus means is provided for heating the adsorbers at times when they are not connected to the evaporator so as to drive off the adsorbed fluid which is, if necessary or desirable, condensed and returned to the evaporator. Such apparatus and the processes carried out thereby are disclosed in the following United States patents:

1,729,081, E. B. Miller, Sept. 24, 1929, Refrigeration;

1,790,757, E. B. Miller, Feb. 3, 1931, Regenerative refrigerating apparatus;

1,862,604, E. B. Miller, June 14, 1932, Refrigeration car.

According to the present invention, in refrigeration apparatus of the type described means are provided for connecting an adsorber which has just been largely freed of adsorbed fluid by heat to another adsorber which has just finished adsorbing vapor from the liquid in the evaporator to produce an improvement in the refrigeration capacity of the apparatus for reasons which will be more apparent as the description of the invention proceeds.

In Fig. 1 of the drawing, two adsorbers 10 and 12, respectively, are shown, but it will be understood that any number can be used with equal facility by slight modifications in the piping arrangement. These adsorbers may each comprise a closed tank substantially filled with a suitable adsorbent material, separated from the ends by screens 13 and 14 and having embedded therein a cooling coil 15 or 16. Each of these adsorbers is connected by a pipe 17 and 18 respectively to the evaporator 19 which may comprise a tank with or without coils or fins to extend its surface and containing a quantity of liquid refrigerant. Each of the evaporators is connected by a pipe 20, 21 to a condenser 22 comprising a tank and a suitable cooling coil 23. Obviously any type of condenser may be used, either air or water cooled. The condenser is provided with a pipe 24 for draining the condensed refrigerant back into the evaporator 19 under the control of a float-actuated valve 25 which separates the so-called "high side" of the refrigeration system from the "low side". The high side includes the adsorber being activated

and the condenser, whereas the low side includes the evaporator and the adsorber which is adsorbing.

Suitable means, represented by gas burners 27, 28, respectively, are provided for heating the adsorbent material in the adsorbers to activate, revivify, or desorb it, and the gas for the burners is provided from the main 29 through the three-way valve 30 so that it can be alternately supplied to the burners.

In normal operation of such a refrigeration system, and one in which cooling water is used may be taken as an example, water is supplied through the pipe 31, passes through the coil 23 in the condenser and through the three-way valve 32 to the coil 15 in the adsorber 10. This cools the adsorbent material therein so that it adsorbs vapors from the liquid in the evaporator 19 through the pipe 17. At the same time, the burner 28 is lighted to heat the adsorber 12 and drive off adsorbed vapor from a previous cycle of operation into the condenser through the pipe 21, where it is cooled by contact with the cold coil 23, liquefied, and returned through the pipe 24 to the evaporator for re-use.

To facilitate the operation, valves 34 and 35 are provided in the pipes leading respectively from adsorbers 10 and 12 to the condenser, one of which is opened while the other is closed. Likewise, valves 36 and 37 are provided in the pipes between the adsorbers and the evaporator, only one of which is open at a time and that being the one connected to the adsorber which is isolated by its valve from the condenser. Manipulation of the valves to reverse the positions of the adsorbers in the cycle may take place either by hand or automatically, as may be desired, in a known manner.

According to the present invention, there is provided an additional connection in the form of pipe 40 from valve 35 to valve 36, or from the top of adsorber 12 to the bottom of adsorber 10, and controlled by the three-way valves to which it connects. Similarly, a pipe 41 leads from valve 34 to valve 37 and it forms a connection between the pipe from the top of adsorber 10 to the condenser and the pipe from the bottom of adsorber 12 to the evaporator which is controlled by these valves, each of which is a so-called "three-way valve".

The benefits of these additional connections will be understood from the following description:

In refrigeration apparatus of the kind referred to, the refrigerating capacity is determined largely by the differences of concentration of the refrigerant in the adsorbent at the end of the heating and the adsorbing or cooling periods.

For any given temperature of the adsorbent, the amount of concentration will vary with the vapor pressure of the refrigerant therein, and conversely, for any given vapor pressure the amount of concentration will vary with the temperature. Thus with high temperatures and low pressures small concentrations exist and with low temperatures and high pressures large concentrations exist.

In the refrigeration apparatus just described, it may be assumed for the purpose of this description that adsorber 12 has been heated and the adsorbent material therein has reached its highest temperature, by which means all the refrigerant possible has been driven out against the pressure of the condenser 22, and the adsorber 10 has been cooled by water flowing in its

coil 15 so that it has reached its lowest temperature and the adsorbent material has taken in and adsorbed all that is possible at the pressure of the evaporator 19.

The object of the invention is to increase the difference of concentration between 12 and 10 without raising the temperature of 10 or lowering that of 12 by external means, over those just described, and by so doing to increase the refrigerating capacity, and improve the efficiency of the apparatus.

The adsorber 12 being on the high side, has a pressure substantially the same as that in the condenser, while the adsorber 10 being on the low side, has a low pressure substantially the same as that in the evaporator. It is clear, therefore, that if at this time open communication between the two adsorbers is made by either of the pipes 40 or 41, or by both, by turning the various three-way valves to appropriate positions, there will be a flow of vapor from 12 to 10 and a lowering of pressure in 12 and a corresponding raising of pressure in 10. The result will be a lower concentration of refrigerant in 12 and a higher concentration in 10, while at the same time the desorption from 12 will tend to lower its temperature and the adsorption by 10 will tend to raise its temperature. The two adsorbers are thus better prepared for their next operations.

If after the pressures in the two adsorbers are substantially equalized, the communication between them is shut off by further turning the three-way valves to now connect adsorber 12 to the evaporator and adsorber 10 to the condenser, and heat is supplied to adsorber 10 and cooling water to adsorber 12, by reversing the three-way valves 29 and 32, then the extra refrigerant which was discharged by 12 into 10 will be driven, along with that quantity which was first taken by 10 from the evaporator, into the condenser, while 12 having been unloaded by the amount of the extra refrigerant, in addition to that which was first discharged into the condenser, will have a greater capacity for adsorption of vapor from the evaporator. If sufficient time is allowed for desorption, the net gain in each cycle over what would be normally obtained, would be the weight of the refrigerant transferred from 12 to 10, or from 10 to 12, depending on which adsorber has just been heated.

As will be readily understood, automatic means may be provided for operating the valves for connecting the adsorbers together at the appropriate times if desired, such automatic means being connected to or operated by any other automatic apparatus provided for changing over the adsorbers from the adsorption stage to the heating stage, and vice versa.

Fig. 2 shows a simplified form of apparatus wherein the details of construction of the parts have been omitted. Here the adsorbers 50 and 51 are equipped respectively with burners 52 and 53 fed from the gas pipe 54 through the three-way valve 55. Each adsorber has a valve box 56 attached thereto containing a pair of check valves. The valve 57 controls the pipe leading to the condenser 58 and opens when pressure in the adsorber is greater than that in the condenser. A second check valve 59 controls the pipe that leads to a common pipe 60 connected by the pipe 61 to the evaporator 62, and this check valve opens when the pressure in the adsorber is less than that in the evaporator. Thus, each adsorber is automatically connected to the con-

denser or the evaporator in accordance with whether or not it is being heated or cooled. The operation of the device is identical with that described in connection with Fig. 1 for normal operation, but the valve change-over is automatic.

In order to provide for communication temporarily between the two adsorbers at about the time when the shift is to be made and during which time it is preferred to have both burners extinguished, the pipe 64 connects the valve boxes 56 together and is equipped with a suitable valve 66 which may be either manually or mechanically operated. For instance, it may be controlled by a timing mechanism which also manipulates the valve 54 to change the cyclic operation of the device.

It will be obvious that when the valve 66 is opened, that the adsorber which has been at high pressure will automatically disconnect itself from the condenser as soon as the pressure in this adsorber becomes slightly less than that in the condenser, and that the adsorber which has been connected to the evaporator will automatically disconnect itself from the evaporator as soon as its pressure becomes slightly greater than that of the evaporator. Thus, in effect, all four check valves will be closed automatically and there will be merely a connection between the adsorbers for the time being.

Refrigerators of the kind described have been employed in connection with the use of silica gel as an adsorbent, and the use of this adsorbent among others, for instance, alumina or other gels, as well as absorbents such as calcium chloride or the like, is contemplated. In addition, adsorbents such as silica gel impregnated with calcium chloride or with other chemical absorbents may be used.

The liquid to be evaporated may be water, in which case the condensers can be dispensed with and the water vapor being driven off from the evaporator by heat merely discharged into the air. In this case some means must be provided for replenishing the water in the evaporator. In connection with silica gel, SO_2 forms a very satisfactory refrigerant, whereas with calcium chloride, ammonia may be used. Ammonia is also satisfactory with certain forms of impregnated gels, as for instance, silica gel impregnated with calcium chloride. Ammonia may also be used with silica gel alone, where this gel is specially treated initially to lower the water content to less than about 10% of its dry weight.

From the above it will be understood that the invention does not reside in the particular refrigerant, adsorbent or absorbent, or in the specific apparatus, but rather in the process which comprises mainly connecting together the two adsorbers which are at maximum pressure difference, and in the apparatus for carrying out this particular step.

In cases where no condenser is present, the invention is useful as permitting the adsorber which has been heated to be brought, prior to its connection to the evaporator, under sub-atmospheric pressure, by a temporary connection to an adsorber which has been used up to that time to adsorb vapor from the evaporator and is thus on the low or sub-atmospheric side of the system.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent is:

1. The process of refrigeration comprising adsorbing vapor from a liquid refrigerant into a

batch of adsorbent, heating a second batch of adsorbent previously used for adsorbing said vapor to revivify it, stopping both processes, transferring vapor from the heated batch to the other batch, and then reversing the positions of the batches in the process.

2. The method of refrigeration in a cyclically operating adsorption refrigeration system having at least two adsorbers comprising the step of connecting together two adsorbers of the system, one at the highest temperature and the other at a low temperature whereby the high temperature is lowered by desorption and the low temperature raised by adsorption.

3. The method of refrigeration is a cyclically operating adsorption refrigeration system having at least two adsorbers comprising the step of connecting together two adsorbers of the system, one at the lowest refrigerant vapor concentration and the other at the highest to further increase the difference in concentration between the two adsorbers.

4. Refrigeration apparatus of the type described comprising, in combination, a pair of adsorbers each having a gas chamber charged with a solid granular adsorbent material, means to alternately heat the masses of adsorbent, an evaporator, a condenser, means to connect the heated adsorber and condenser, means to connect the other adsorber to the evaporator, and means to place said gas chambers in communication prior to the adsorbers reversing their positions in the cycle whereby gas flows from the heated adsorbent mass to the other mass until the pressures are substantially equalized.

5. Refrigeration apparatus of the type described including, in combination, a pair of adsorbers each having a gas chamber charged with hard porous adsorbent material, means to alternately heat said adsorbers to revivify them, an evaporator containing refrigerant liquid, means to discharge vapor driven off from the heated adsorbent, means to connect the other adsorber to said evaporator to adsorb vapor from the liquid therein, means to shift the relation of the adsorbers in the cycle, and means to place said gas chambers in communication prior to the shift so that vapor flows from the heated adsorber to the other adsorber until the pressures in the gas chambers are substantially the same.

6. Refrigeration apparatus of the type described including, in combination, a plurality of adsorbers each having a gas chamber charged with hard porous adsorbent material, means to heat said adsorbers in succession to revivify the adsorbent material therein, an evaporator containing liquid refrigerant, means to discharge vapor driven off from the heated adsorber, means to connect a revivified adsorber to the evaporator to adsorb vapor from the liquid therein, means to shift the relation of the adsorbers in the cycle to replace the one filled with vapor by a fresh one and to heat the filled one, and means to place in communication the gas chamber having the highest pressure therein and the gas chamber having the lowest pressure for a brief period at the time of said shift whereby vapor flows from one chamber to the other until the pressures are substantially equalized.

7. Refrigeration apparatus of the type described, in combination, a plurality of adsorbers each having a gas chamber charged with hard porous adsorbent material, means to heat said adsorbers in succession to revivify the adsorbent therein, an evaporator containing liquid refrigerant

erant, means to discharge vapor driven off from the heated adsorbent, means to connect a revived adsorbent to the evaporator to adsorb vapor from the liquid therein, means to shift the relation of the adsorbers in the cycle to replace the one filled with vapor by a fresh one and to heat the filled one, and means to place said gas chambers in direct communication after heating the filled adsorbent to effect flow of vapor from the heated adsorbent to the other one.

8. Adsorption refrigeration apparatus including, in combination, an evaporator containing liquid refrigerant, a condenser, a plurality of adsorbers each having a gas chamber charged with hard porous adsorbent material, piping connecting said parts forming a circuit, valves whereby any adsorbent can be connected to the evaporator and any to the condenser, means to heat the adsorbent connected to the condenser to drive out the adsorbed vapor and revivify the adsorbent material, means to return the condensed vapor to the evaporator, and means to place in communication the gas chamber of a freshly revived adsorbent and one charged with vapor before exchanging their positions in the circuit to transfer vapor from the freshly activated adsorbent to the other.

9. The process of refrigeration consisting in adsorbing vapor from a liquid refrigerant in a batch of hard porous adsorbent material in a closed gas chamber, heating a batch of solid porous adsorbent material in another gas chamber and previously used for adsorbing vapor from the refrigerant to revivify it and condense the vapor in a closed chamber, isolating said batches from the refrigerant liquid, placing said gas

chambers in communication until substantially equilibrium of vapor pressure is obtained, and then reversing the original operations on the batches.

10. The process of refrigeration with apparatus including a plurality of adsorbers having gas chambers charged with solid porous adsorbent material, an evaporator having liquid refrigerant therein, and a condenser, consisting in connecting one chamber to the evaporator to adsorb vapor from the liquid therein, connecting another of said chambers to the condenser, heating the adsorbent material in the latter to drive out the vapor, stopping the heating, placing the two gas chambers in communication until substantially equilibrium of vapor pressure is attained, and subsequently using the heated adsorbent to adsorb the vapor from the evaporator.

11. The method of refrigeration in a cyclically operating adsorption refrigeration system having at least two gas chambers, each charged with hard porous adsorbent material, consisting in the step of placing the gas chambers in communication, one of said gas chambers having freshly activated adsorbent therein and another gas chamber having partially saturated adsorbent therein, for the purpose of further desorbing said freshly activated adsorbent and to lower its temperature.

12. The method of refrigeration in a cyclically operating adsorption refrigeration system having at least two gas chambers, each charged with hard porous adsorbent material, consisting in the step of placing in communication two of said chambers, one at the highest pressure and the other at the lowest until these pressures are substantially equalized.

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