

April 19, 1960

H. J. E. JOHANSSON ET AL

2,932,958

HEAT PUMP

Filed Nov. 24, 1953

3 Sheets-Sheet 1

Fig. 1

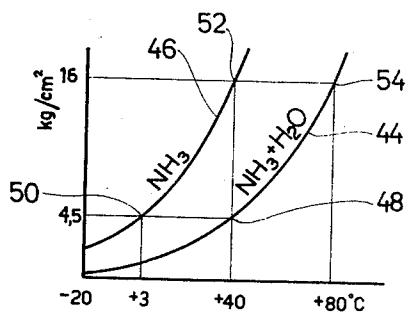
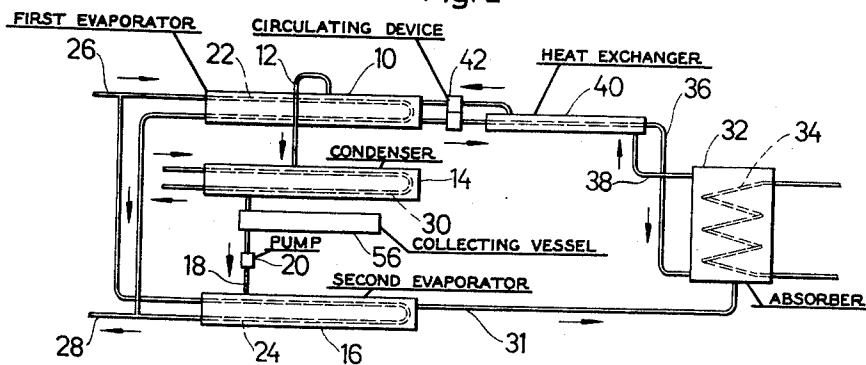


Fig. 2



Inventor:
Hilding Jonas Elias Johansson
Per Johan George Thorsbäck
By Jarvill M. M. M.
their Attorney

April 19, 1960

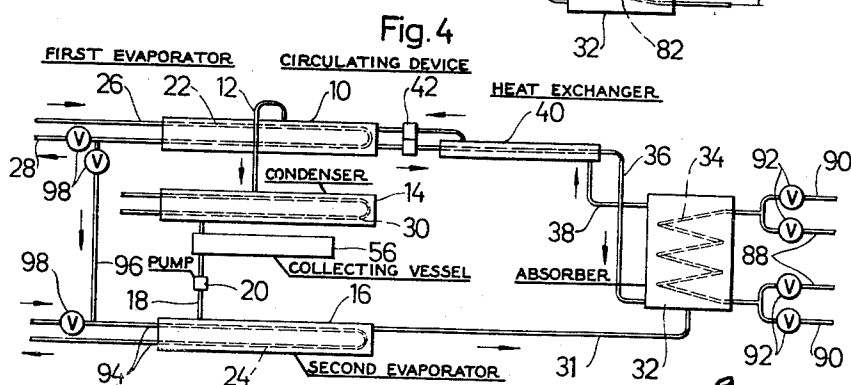
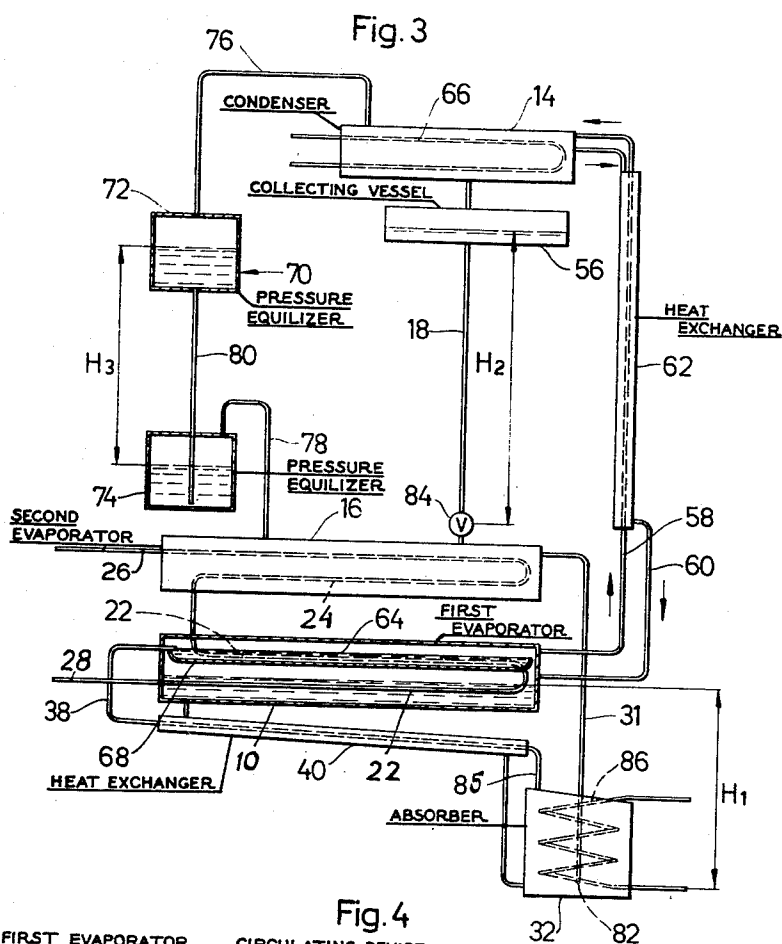
H. J. E. JOHANSSON ET AL

2,932,958

HEAT PUMP

Filed Nov. 24, 1953

3 Sheets-Sheet 2



Inventors
 Holger Jonas Einar Johansson
 Per Johan Gorge Norbäck
 By *Jarval M. M. M.*
 Their Attorney

April 19, 1960

H. J. E. JOHANSSON ET AL

2,932,958

HEAT PUMP

Filed Nov. 24, 1953

3 Sheets-Sheet 3

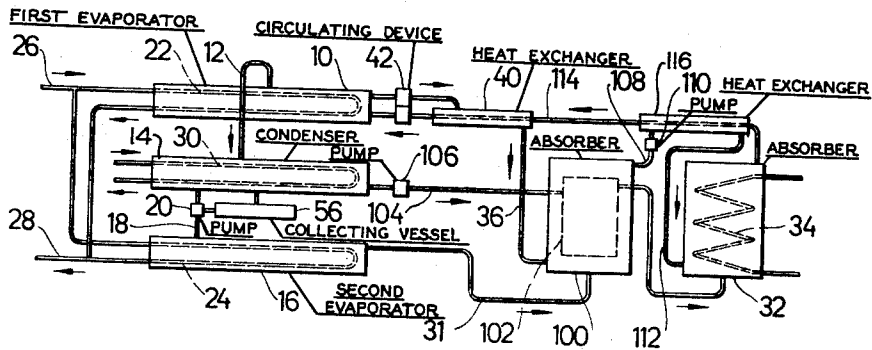
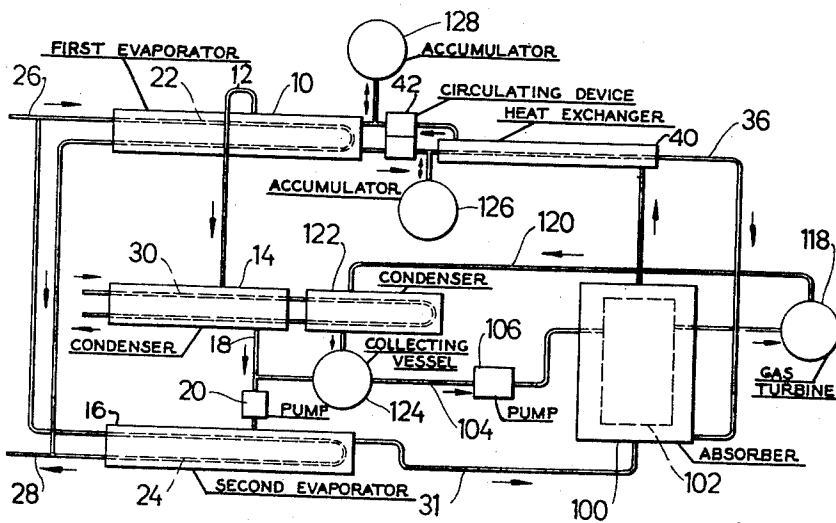


Fig. 5

Fig. 6



Inventors:
 Hilding Jacob Elias Johansson
 Per Johan Jönas Norbäck
 By *J. J. Smith*
 Their Attorney

1

2,932,958

HEAT PUMP

Hilding Jonas Einar Johansson and Per Johan George Norbäck, Hagfors, Sweden

Application November 24, 1953, Serial No. 394,158

1 Claim. (Cl. 62—476)

Our invention relates to a heat pump.

In the industry, heat is frequently obtained in processes of various kinds, as in the cooling of furnaces, generators, power engines, etc. This heat is often of so low a temperature as not to allow suitable utilization thereof for heating purposes or transformation into mechanical energy. Large quantities of heat are also to be found in nature, which quantities it has hitherto not been economically profitable to utilize. It would then be necessary to transform this heat into a higher, more serviceable temperature. It is conceivable to effect this transformation by means of the so-called heat pump operating, in principle, as an ordinary compressor-driven refrigerating machine with evaporation and condensation of a heat absorbing fluid, higher temperatures being obtained in the condenser. The drawbacks inherent in this system are that high pressures are required, for which reason the compressors become expensive, while the operating and maintenance costs will also be considerable.

The main object of our present invention is to provide a system operating according to the same fundamental principle, still with the difference that an upward transformation of temperature is obtained without a compressor. Due to this feature the plant becomes cheaper, while the operating and maintenance costs will be minimal. The energy required for the upward transformation is taken from the heat energy existing in the medium which yields heat. The system provides for the vapor pressure of the heat absorbing fluid being reduced during a part of the circulation cycle.

Further objects and advantages of our invention will be apparent from the following description considered in connection with the accompanying drawings which form part of this specification, and of which:

Fig. 1 shows a diagram,

Figs. 2 to 6 more or less diagrammatically illustrate five embodiments of the invention.

Referring to the drawings, reference numeral 10 designates a first evaporator which contains a refrigerating fluid and an agent for decreasing the vapor pressure thereof. Said fluid may consist of ammonia, NH_3 , and the agent of water, in which the ammonia is being dissolved. A conduit 12 connects the evaporator 10 with a condenser 14. A second evaporator 16 communicates with the condenser 14 through a conduit 18 in which a pump or sluice 20 is provided. In the evaporators are disposed conduits such as coils 22 and 24 connected in parallel and through which pass a heat yielding medium, said medium entering through a conduit 26 and escaping through a conduit 28. The heat yielding medium is taken from an available heat yielding source such as escaping cooling water from a power plant which normally is allowed to escape without being made use of. Said cooling water is assumed in the following description to have a temperature of 40° C. The condenser 14 is also provided with a conduit such as a coil 30 for conducting a heat absorbing fluid such as sea water which is taken

2

from the surroundings and the temperature of which is largely dependent upon climatic conditions.

In the evaporator 10 the refrigerating fluid evaporates and leaves the evaporator through the conduit 12 in which a water separator of known construction may be disposed. The vapors of the refrigerating fluid are condensed in the condenser 14 under the same pressure as that prevailing in the evaporator 10. The liquid refrigerating fluid is then pumped by the pump 20 into the second evaporator 16 in which a higher pressure prevails due to the withdrawal of the pressure reduction agent and which is heated by the heat yielding medium in the same manner as the evaporator 10. The available heat yielding source has thus been used to increase the pressure in the refrigerating fluid and thus performs the same work as the compressor in a compressor driven heat pump.

The vapors of the refrigerating fluid escape from the evaporator 16 through a conduit 31 to an absorber 32 containing in the same manner as the evaporator 10 an agent for decreasing the vapor pressure. The vapor is absorbed by said agent and the heat of condensation is given up to raise the temperature. The heat produced in the absorber is conducted therefrom by means of a conduit such as a coil 34.

Since the refrigerating fluid in the absorber 32 continuously becomes more concentrated by the vapor pressure decreasing agent, said fluid is forced to circulate between the absorber and the evaporator 10. For this purpose said elements are interconnected by conduits 36, 38, which over part of their longitudinal extension are formed as countercurrent heat exchangers 40 adapted to counteract losses in heat. Said conduits further comprise a circulating device 42. Said circulating device 42 may take the form of a combined liquid pump and liquid motor of the screw type, the construction of which even pays regard to the higher pressure prevailing in the absorber. As the circulating device 42 circulates liquid both in the direction from and the direction towards the higher pressure the consumption of power in the circulating device 42 will remain very small. The pump 20 also consumes little power since it conveys liquid only in the direction towards the higher pressure.

The diagram presented in Fig. 1 illustrates the vapor pressure as a function of the temperature indicated in centigrades. The curve 44 shows the vapor pressure for the mixture of the refrigerating fluid, which in the example under consideration is ammonia, NH_3 , and the vapor pressure decreasing agent, which in the example under consideration is water, H_2O , whereas the curve 46 shows the vapor pressure for the pure refrigerating fluid. The heat yielding source has a temperature of 40° C., as indicated above. It is further assumed that the pressure in the evaporator 10 is 4.5 kg./cm.². The condition prevailing in the evaporator corresponds to point 48 in the diagram. In the condenser 14 the ammonia while remaining under unchanged pressure is cooled down to 3° C. which is assumed to be the temperature of the heat absorbing fluid (inevitable drop of temperature between the different media is disregarded in this connection). In the condenser the ammonia has thus reached point 50 of the diagram. The pump 20 increases the pressure of the condensed ammonia to 16 kg./cm.² corresponding to point 52 in the diagram. In the absorber 32 the ammonia is absorbed by the water at said high pressure, and the temperature then rises to 80° C. corresponding to point 54 of the curve 44. The cycle is completed by returning the highly concentrated mixture of ammonia and water to the evaporator 10 in which according to the diagram the conditions prevailing are represented by the point 48.

The larger the reduction of the vapor pressure, the higher will be the temperature obtained in the absorber. How-

ever, the vapor pressure must always be so high as to ensure condensation in the condenser 14 at the temperature dependent of the refrigerating fluid.

In practice one has usually to contend with variations of the temperature of the heat absorbing fluid or the heat yielding source, respectively. In such cases it is of great importance that there exists a possibility of varying the reduction of the vapor pressure in response thereto in order to obtain the highest possible temperature in the absorber 32. For this purpose a collecting vessel 56 is interposed between the condenser 14 and the pump 20 to the conduit 18. Said vessel thus will contain pure refrigerating fluid in liquid state. If the temperature prevailing in the condenser 14 becomes lower, the condensation will take place more quickly. The same result is obtained if the temperature in the evaporator 10 rises and in connection therewith the vapor pressure of the refrigerating fluid is increased. The liquid stream between the condenser 14 and the evaporator 16, however, is controlled by the pump 20. Thus, if the condensing process becomes more rapid, refrigerating fluid will be collected in the vessel 56 which will result in that the concentration of refrigerating fluid in the vapor pressure decreasing agent in the absorber 32 and the evaporator 10 will be reduced. Consequently the decrease of the vapor pressure will become larger and the temperature in the absorber will rise until a state of equilibrium has been reached. If, on the other hand, the temperature in the condenser rises or the temperature in the evaporator drops, the intensity of the condensation process will fall but as vapor of the refrigerating fluid is fed into the absorber in a constant quantity per unit of time, the concentration of the vapor pressure decreasing agent in said absorber will be increased, and finally a sufficient pressure for condensation in said condenser will be obtained by the continuous circulation of mixture passing between the absorber and the evaporator 10.

In the device now described, the reduction of the vapor pressure will continuously and automatically become adjusted to the difference in the temperatures of the heat yielding source and the heat absorbing fluid, respectively. It is evident that the upward transformation of temperature will become the longer, the larger temperature difference is available.

The embodiment according to Fig. 3 differs from the preceding one by the apparatus containing a pressure equalizing inert gas. Said gas is thus under a pressure corresponding to the pressure difference between the high pressure side and the low pressure side of the apparatus constructed according to the preceding embodiment. The inert gas permits dispensing with pumps and similar means for influencing the flow of the media between the various parts of the apparatus. The inert gas fills the space not occupied by liquid in the evaporator 10, the condenser 14, and the collecting vessel 56. In the embodiment illustrated the condenser 14 is located at a higher level than the evaporator 10, for which reason the inert gas has to be heavier than the vapor pressure decreasing agent. If this latter is constituted by ammonia the inert gas may be nitrogen. If both elements of the apparatus are located in reversed order the inert gas should be lighter than the agent.

The evaporator 10 and the condenser 14 are interconnected by two conduits 58 and 60, which over part of their longitudinal extension are formed to constitute a heat exchanger 62. The conduit 58 is connected to each of said vessels near the top thereof and extends there-through by means of conduit portions 64 and 66, respectively. Both conduits open into the vessels above the surface of the liquid present therein. The evaporator 10 may be provided with one or several inclined plate members 68 over which the solution having a high concentration of refrigerating fluid returning from the absorber 32 through the conduit 38 is permitted to flow. In this way the solution is given an improved heat con-

tact with the heated conduit coil 22 and at the same time a large evaporation surface is obtained. By evaporation of the refrigerating fluid performed in the evaporator 10 the gas mixture present above the liquid becomes concentrated by vapor of said fluid. In the condenser 14 where the vapors of the heat absorbing fluid are condensed into liquid state the gaseous atmosphere will have a low concentration of vapors of said fluid. This will result in a circulation between the two vessels in question in such a manner that the gas mixture in the evaporator 10, which has a large concentration of refrigerating fluid and therefore relatively low specific gravity, will rise in the conduits 58 while the heavier gas mixture in the condenser 14 will descend the conduit 60. Both of such gas flows will exchange heat in the heat exchanger 62.

A pressure equalizer or regulator generally denoted by 70 is inserted between the condenser 14 and the second evaporator 16. Said pressure equalizer comprises two containers 72 and 74 displaceable relative to one another with respect to their height position for adjustment purposes. Both are partly filled with a liquid, such as oil, which does not absorb the refrigerating fluid. The upper container 72 and the condenser 14 are at their top interconnected by means of a conduit 76. A conduit 78 extends from the upper part of the lower container 74 and opens into the upper part of the evaporator 16. The containers 72 and 74 are interconnected by a conduit 80 extending from the liquid filled portion of the upper container to the liquid filled portion of the lower container.

The pressure equalizer 70 is intended to adjust the pressure prevailing in the inert gas in relation to the pressure of the vapor of the refrigerating fluid in the condenser 14 and the evaporator 16. The pressure of the vapor of the refrigerating fluid in the condenser is substantially lower than in the evaporator 16 and the magnitude of said pressure difference is influenced by the temperature of the heat yielding and the heat absorbing sources. As the evaporator 16 contains only an atmosphere of vapor of the refrigerating fluid the pressure in said vessel depends only on the temperature and is independent of the volume of the vessel, whereas on the side of the apparatus filled with the inert gas the pressure of said gas is reduced if the volume is increased and vice versa. The liquid surface in the communicating vessels 72 and 74 thus always is displaced so as to obtain equivalence in pressure.

The absorber 32 is located below the evaporator 10 and this latter in turn below the evaporator 16. The conduit 31 thus extends downwards from the evaporator 16 to the absorber 32 into which it opens near the bottom thereof. Between the lower opening 82 of the conduit 31 and the liquid level in the evaporator a liquid column is created the heat of which is indicated by H_1 . In order to allow the vapors of the refrigerating fluid to pass through the conduit 31 a liquid column therein corresponding to the liquid column H_1 must be displaced. This displacing is brought about by means of the pressure equalizer 70 containing a liquid column indicated at H_3 , the rate of which is larger than that of the column H_1 . The weight of the liquid columns in question is determined partly by their vertical extension and partly by the specific gravity of the two liquids in question which gravity may be greater for the liquid located in the pressure equalizer.

The conduit 18 connecting the collecting vessel 56 with the evaporator 16 contains a member 84 responsible to temperature and thus insuring a flow, depending on the temperature of the heat yielding source, of condensate of the refrigerating fluid from the collecting vessel to the evaporator 16. The weight of the liquid column H_2 between the member 84 and the liquid surface in the collecting vessel 56 is greater than the weight of the liquid column H_3 which results in the condensate, due to its own weight, automatically flowing through the conduit 18 to the evaporator 16.

Upon starting of the apparatus the vapors of the refrigerating fluid produced in the evaporator 16 will flow through the conduit 30 into the absorber 32. The temperature in this latter will rise, and at the same time the concentration of the refrigerating fluid in the pressure decreasing agent will be increased. The desired temperature having been reached and the liquid fluid becoming saturated with vapors of the refrigerating fluid, vapor will pass through the absorber upwardly to a portion 85 of the return conduit 38. Said vapor will reduce the weight of the liquid column existing there and cause a boiling or siphon effect lifting the returning liquid to the opening of the tube 38 located above the level of the liquid on the bottom of the evaporator 10. In order to facilitate the entry of the vapor into the conduit 38 the upper side of the absorber 30 may incline toward the lower opening of the conduit portion 85.

An apparatus constructed according to our invention may be utilized for alternately producing heat and cold, for example in air conditioning during both winter and summer. An apparatus of this kind is illustrated in Fig. 4. Said embodiment differs from that shown in Fig. 2 only by the feature that the conduit 34 provided in the absorber 32 is connected to two circulation conduits 88 and 90, respectively, each controlled by a valve 92. One of said circulation conduits is used for heating and the other for supply of a refrigerating fluid such as water, for example, the temperature of which is below that of the heat yielding source introduced through the conduit 26. The heat yielding source may be constituted by air having the temperature of the ambient atmospheric air. If desired, this air may be heated further, for example by causing it to pass roof surfaces heated by the sun. The produced cold may be taken out from the condenser 16 through a conduit system 94. Said system and a branch pipe 96 connecting the conduit 28 with said system is provided with valves 98 adapted to establish requisite adjustments in the way of flow in response to the kind of conditioning desired.

As an example it may be mentioned that with a temperature of the ambient air of 32° C. and a temperature of the refrigerating fluid of 20° C., a temperature of 10° C. is attainable in the evaporator 16 if inevitable heat losses in the apparatus are disregarded.

If the available difference in temperature is small or a higher temperature than that attainable with a single apparatus of the construction described above is desired, a second apparatus may be attached thereto, said second apparatus operating with the higher temperature reached by means of the first circulation. As illustrated in Fig. 5, it is also possible to cause part of the refrigerating fluid escaping from the condenser 14 to evaporate at the higher temperature reached in the absorber 100. Said absorber is fed with vapors of the refrigerating fluid having the pressure prevailing in the evaporator which in the embodiments described is assumed to be 16 kg./cm.². In the absorber 100 the vapors are absorbed by the solvent by which measure a temperature rise is obtained which in the example set forth is 80° C. Within the absorber is located a second vessel 102 supplied with refrigerating fluid from the condenser 14 through a conduit 104 and by a pump 106. The container 102 is heated to the temperature of the absorber and the pressure of the vapors of the refrigerating fluid is increased to about 42 kg./cm.² under the conditions assumed in the example. Said vapors becoming absorbed by the solvent in the absorber 32 a temperature of about 130° C. is reached.

The solution having a large concentration of refrigerating fluid when leaving the absorber 100 is by a pump 110 subjected to the high pressure existing in the absorber 32 and is then introduced into the same through a conduit 112. The conduit 108 and the return conduit 114 from the absorber to the evaporator 10 comprise a heat exchanger 116. The conduit 114 is provided with a further heat exchanger 40 located between the circulat-

ing device 42 and the heat exchanger 116. The heat exchanger 40 is intended for exchange of heat between the solvent flowing through the conduit 36 to the absorber 100 and having a low concentration of the refrigerating fluid and the solvent returning from the absorber 32 and having a high concentration of said fluid, said last-mentioned solution, after having passed through the heat exchanger 116, having in the conduit 114 a temperature of about 80° C.

As will be seen from Fig. 6, the difference in pressure between the absorber and the condenser may be used for producing mechanic or electric power. The vapor of the refrigerating medium is caused to pass from the maximum temperature and the maximum pressure to the condenser through an expansion engine, such as a gas turbine 118. The embodiment according to Fig. 6 differs from the preceding embodiment substantially by the feature that the absorber 32 is replaced by the engine 118. The pressure drop between the vessel 102 and the condenser 14 which in the embodiment illustrated amounts to 37.5 kgs. is utilized in the engine 118 which is passed by pure vapors of the refrigerant fluid. These vapors are conducted to the condenser through a conduit 120. Said condenser may be divided into two elements, of which the one denoted by 122 is connected to a collecting vessel 124 that is further connected with the conduit 18 and the supply conduit 104 leading to the vessel 102. The collecting vessel 124 constitutes an accumulator collecting condensate of the refrigerant fluid when less power is consumed by the engine 118 in order to supply the accumulated condensate to the engine when consuming more power. The conduit 36 also contains an accumulator 126 which during periods of reduced consumption of power collects a pressure decreasing agent having a low concentration of refrigerating fluid. In this way the delivery may be dimensioned for average consumption of power.

While several more or less specific embodiments of our invention have been described above it is to be understood that this is for the purpose of illustration only and that our invention is not to be limited thereby, but its scope is to be determined by the appended claim.

What we claim is:

A heat pump for utilizing the difference in temperature between a heat yielding and a heat absorbing source which difference is varying, including a first evaporator, a condenser, a second evaporator, an absorber, conduit means for connecting said members in series in the order named, conduit means for connecting said absorber and said first evaporator in a closed circuit for circulating a pressure reducing agent and a refrigerating medium therebetween, means for heating said first evaporator by the heat yielding medium to form vapors of the refrigerating medium, means for condensing said vapors in said condenser by the heat absorbing medium, means comprising an adjustable pressure regulating means connected between said condenser and said second evaporator to compensate for variations in temperature of said heat yielding and said heat absorbing sources, means to evaporate said liquid refrigerating medium in the second evaporator, said vapors from said second evaporator being absorbed in said absorber by said agent, means in said circuit to maintain a higher vapor pressure in said absorber than in said first evaporator, and a vessel provided between said condenser and said absorber for withdrawing a varying quantity of refrigerating medium from said circuit to accommodate the pressure of said medium at said absorber and said first evaporator according to the temperatures of the heat yielding and absorbing sources.

References Cited in the file of this patent

UNITED STATES PATENTS

1,683,434	Altenkirch	Sept. 4, 1928
1,918,820	Nolcken	July 18, 1933