

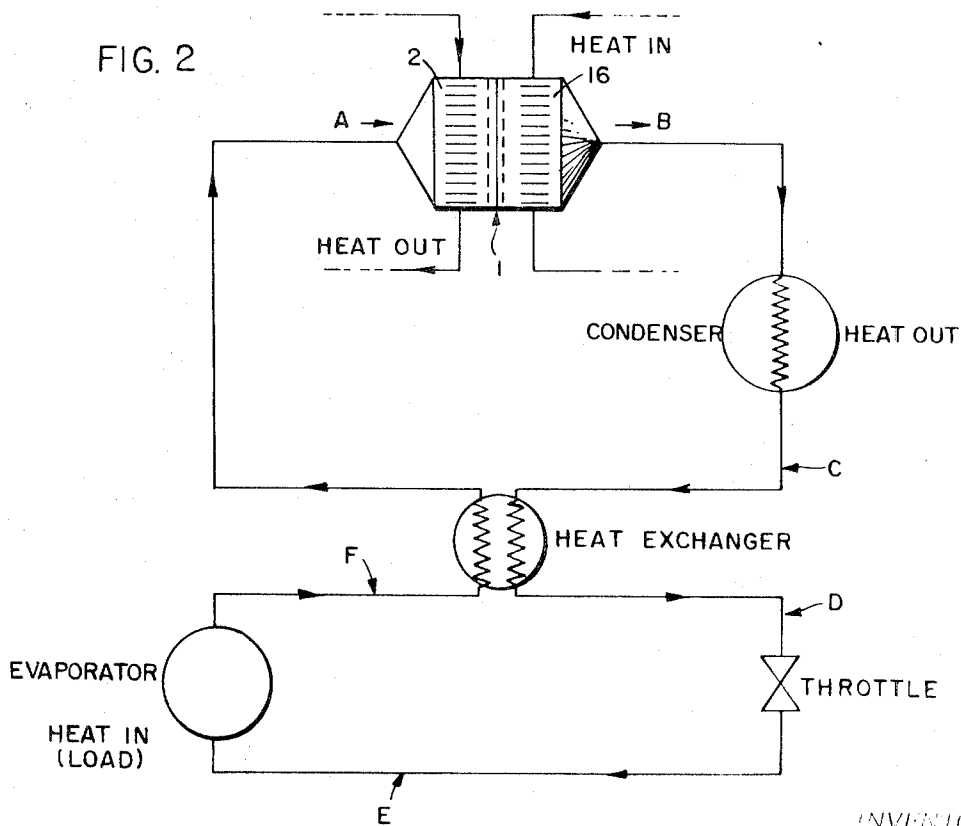
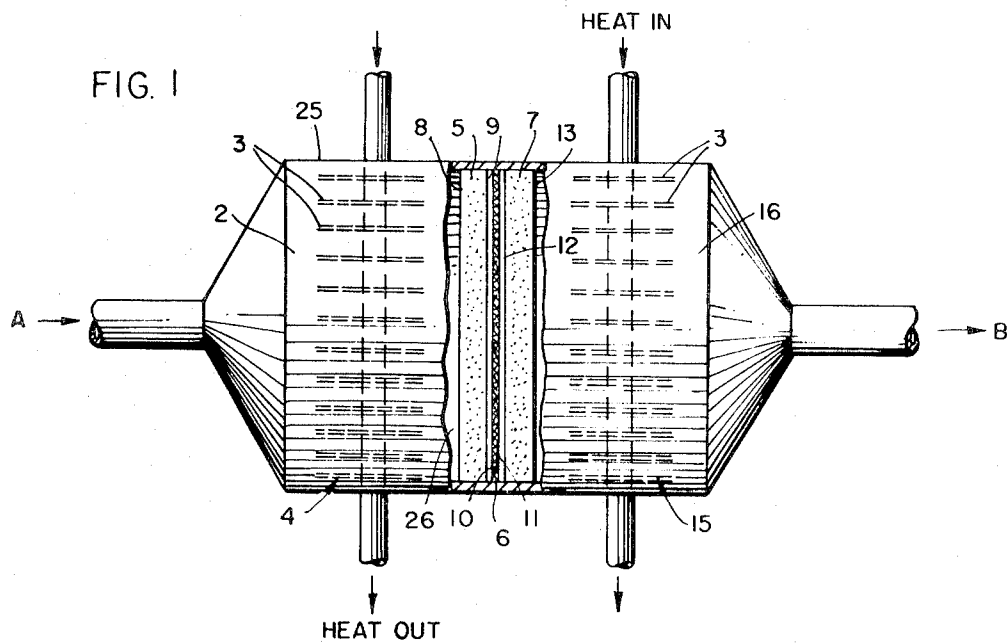
Nov. 23, 1971

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3,621,665

THERMAL PUMP AND PROCESS

Filed Nov. 28, 1969



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3,621,665

THERMAL PUMP AND PROCESS

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Filed Nov. 28, 1969, Ser. No. 880,732

Int. Cl. F25b 7/00

U.S. Cl. 62—79

15 Claims

ABSTRACT OF THE DISCLOSURE

Thermal pump and process for pumping gases by contacting a gas of relatively low pressure and low temperature with one face of a non-porous permeable membrane supported on both faces by rigid porous material, passing the gas through the membrane by means of solution therein, evaporating gas from solution in said membrane at the other face of said membrane, the evaporated gas being at a higher temperature and higher pressure than before its passage through the membrane, heat-exchange means being placed on both sides of the membrane.

Compressors and pumps of the prior art move gas from a low pressure area to a high pressure area by mechanical means. Typically, rotary, reciprocating or other types of pumps having many moving parts are used. Pumps with moving parts are subject to mechanical breakdown for various reasons including wear and general lack of upkeep. Another problem common to pumps and compressors having moving parts is noise. These problems have been particularly severe in compressors and pumps used in cooling devices, which often require continuous operation over long periods of time.

In my invention, the above problems associated with pumps having many moving parts have been eliminated by use of a novel thermal pump and process which can compress a gas without the use of moving parts. Specifically, a gas is moved from an area of lower pressure to an area of higher pressure by passing through a non-porous permeable membrane by means of solution.

My invention requires no moving parts to accomplish its pumping action. Therefore, there is no chance of mechanical breakdown due to wear between moving parts. Also, there can be no noise.

Some permeable membranes having one face exposed to a particular relatively low pressure and low temperature gas will allow passage therethrough by means of solution of the gas in the membrane and subsequent evaporation of the gas at the other face of the membrane, which is exposed to the same gas at a relatively higher temperature and higher pressure. If a suitable cooler and a suitable heater are placed proximate to the low temperature and high temperature faces, respectively, gas will continue to move from the low pressure side of the membrane to the high pressure side, entering the membrane by means of exothermic solution at the membrane face on the low temperature side, moving in solution through the membrane, and evaporating at the membrane face near the high pressure and high temperature side as heat is provided by the heater.

The terms "low" and "high," when used to modify pressure or temperature are used in a relative sense herein, that is, relating the gas conditions on opposing sides of the membrane. This invention is operable over wide ranges of pressure and temperature, limited only by the use intended and by structural and operational factors.

It is one object of this invention to provide a pump and process for pumping which overcomes many problems of pumps of the prior art.

It is another object of this invention to provide a pump

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and process for pumping requiring substantially no moving parts.

It is a further object of this invention to provide a thermal pump and process for pumping which moves gas by means of solution with a non-porous permeable membrane.

Yet another object of this invention is to provide a pump and process for pumping which is substantially free of noise.

Still another object of this invention is to provide a thermal pump and process for pumping which can be used in a wide variety of pumping and compressing applications including with cooling devices.

Another object of my invention is to provide a thermal pump and process for pumping using a non-porous permeable membrane having the same material on both faces thereof.

These and other important objects will become apparent from the following description and from the drawings showing preferred embodiment wherein:

FIG. 1 is a partial cutaway plan view of a thermal pump of this invention.

FIG. 2 is a schematic drawing of a cooling system using a thermal pump of this invention.

Referring specifically to FIG. 1 a thermal pump of this invention is shown having container 25 defining passageway 26, inlet passage 2, outlet passage 16, inlet thermal exchanger 4, outlet thermal exchanger 15, fins 3 on both of the thermal exchangers, permeable membrane 6 having membrane first face 10 and membrane second face 11, first porous structure 5 having first porous structure first face 8 and first porous structure second face 9, and second porous structure 7 having second porous structure first face 12 and second porous structure second face 13. The permeable membrane extends across passageway 26 and with container 25 defines inlet passage 2 and outlet passage 16.

A gas enters thermal pump inlet passage 2 at A at a temperature of T_1 and a pressure of P_1 . The same gas may be in outlet passage 16 at a temperature of T_2 , higher than T_1 , and pressure of P_2 , higher than P_1 . The gas in inlet passage 2 passes through first porous structure 5, contacts membrane first face 10 and goes into solution with permeable membrane 6 at membrane first face 10. As the gas goes into solution, the heat of solution is absorbed by inlet thermal exchanger 4, said inlet thermal exchanger being proximate to first porous structure 5 and therefore also to membrane first face 10. Inlet thermal exchanger 4 may also absorb some sensible heat of the gas and heat which is conducted through the membrane from high temperature outlet passage 16.

The dissolved gas flows in solution through permeable membrane 6. As heat is provided by outlet thermal exchanger 15, the dissolved gas evaporates from solution in the permeable membrane at membrane second face 11. Besides absorbing heat which becomes the heat of solution, the gas absorbs additional heat from the outlet thermal exchanger. The gas, at pressure P_2 , greater than P_1 , and temperature T_2 , greater than T_1 , exits thermal pump outlet passage 16 at B. The thermal pump may serve to move gas or to increase gas pressure in a reservoir.

The theory of gas flow in solution with a non-porous permeable membrane is not completely understood. I have observed that the volume of gas flow is related to the pressure gradient across the membrane. A relatively large pressure gradient across a permeable membrane generally will cause a relatively high rate of gas flow in solution from the high pressure to the low pressure side. A relatively large thermal gradient across a permeable membrane will generally cause a relatively high rate of

flow from the low temperature side to the high temperature side. The effect of a high thermal gradient can overcome the effect of a pressure gradient and thus allow flow of gas from low pressure and low temperature side to high pressure and high temperature side. In the thermal pump and process of this invention, a relatively high thermal gradient and a relatively low pressure gradient are preferred. Specifically, a thermal gradient high enough to overcome gas flow in solution caused by the existing pressure gradient is required. As the pressure gradient becomes large, its effect on gas flow in solution will overcome the effect of the large thermal gradient. Thus, if the thermal pump is being used as a compressor to raise the pressure of a gas in the reservoir, its effectiveness will diminish as the pressure gradient becomes too large with respect to a given thermal gradient. Therefore, there is a practical limit to the high pressures which may be achieved. The relative solubility of a gas in a membrane at the differing pressure and temperature conditions and the resultant concentrations of solution at the membrane faces are probably important factors in gas flow in solution with a non-porous permeable membrane. I have found that the flow rate varies inversely with the level of pressure of the system, temperatures and temperature gradient being constant.

Referring specifically to FIG. 2, a cooling system is shown having thermal pump 1 of FIG. 1, condenser, heat exchanger, throttle and evaporator. The thermal pump of this cooling system replaces the motor driven compressor, or the absorber and generator of an absorption system. It is a source of compressed gas. The outlet thermal exchanger provides heat to maintain the desired high thermal gradient between the inlet passage and the outlet passage. After passing through the thermal pump and exiting at B, the gas has pressure P_b and temperature T_b . It enters the condenser and leaves as liquid at pressure P_c and temperature T_c . T_c is lower than T_b , and P_c is substantially the same as P_b . The cooling and change of phase occurs because of heat rejection in the condenser. The condensed liquid is cooled in the heat exchanger to temperature T_d , pressure P_d being substantially the same as P_c . The condensed liquid is then throttled to relatively low pressure P_e and relatively low temperature T_e . The liquid then enters the evaporator where it evaporates upon picking up the heat load. The pressure P_f is approximately the same as P_e , and temperature T_f is approximately the same as T_e . Then the gas passes through the heat exchanger, its temperature increasing to T_a , P_a being substantially the same as P_f .

The porous structures referred to above offer only negligible resistance to gas flow. Gas may enter first porous structure 5 at first porous structure first face 8 and exit second porous structure 7 at second porous structure second face 13 with substantial freedom. The porous structures provide support for permeable membrane 6, which is placed between said porous structures, membrane first face 10 being against first porous structure second face 9 and membrane second face 11 being against second porous structure first face 12. The material used for porous structures may be any material which would provide adequate support for the membrane and allow substantially free passage of gas. Another important factor to be considered in choosing material for the porous structures is conductivity. It is highly preferable that the porous structures have a high thermal conductivity to enable adequate passage of heat both to and from the non-porous permeable membrane. Preferred materials are highly porous to allow substantially free passage of gas, strong and of even texture to provide rigid support for the membrane, and of a high conductivity. Examples of preferred materials are porous ceramic and porous metallic pieces. Especially preferred materials are porous bronze, steel and copper. The thickness may vary widely, the considerations being degree of support, passage of gas and conduction of heat. Durability and corrosion re-

sistance are other factors to be considered in choosing a material for the porous structures.

The permeable membrane of this invention must be of a material which can serve as a solvent for the gas being used. The membrane must be non-porous, that is, gas must not be allowed to pass therethrough free of solution. It is also necessary that the solubility of the gas in the membrane be higher at the lower pressure and temperature conditions which will be used than at the higher pressure and temperature conditions. It is highly preferred that the membrane have a low thermal conductivity; lower conductivity will provide higher efficiency in the thermal pump as a high thermal gradient is more easily maintained. The membrane must be chosen in reference to the gas to be used and vice versa.

The thickness of the membrane may vary over wide ranges, keeping in mind that thinness favors gas passage and thickness allows less undesired heat conduction. These factors must be balanced. A preferred range is from .001 to .010 inch. I have found in my work that approximately .002 inch is a favorable thickness for natural rubber latex. The membrane face area may vary over a large range, depending upon configuration, capacity and requirement of associated apparatus.

Although the membrane will normally be made of one material and have that material on both faces thereof, by ganging several membrane layers a larger thermal gradient may be obtained across the membrane. The permeable membrane may be laminated, and may contain different materials.

Any gas which cannot be condensed at the desired operating conditions within the thermal pump and will be dissolved in the permeable membrane being used is suitable for this invention. If the thermal pump is to be used in a cooling application as in FIG. 2, the gas must be such that it will condense at the proper pressure and temperature conditions.

As previously mentioned, the gas must be chosen in view of the choice of permeable membrane. A preferred combination of gas and permeable membrane is carbon dioxide with natural rubber latex. Especially preferred combinations are Freon 11, Freon 12 and Freon 22 with natural rubber latex. Freon designates a group of halogenated hydrocarbons containing one or more fluorine atoms which are used as refrigerants.

The container for the thermal pump may be made in a wide variety of shapes and sizes. The container must be substantially airtight except as indicated at A and B. The container may be made of any material which would serve as support for the various components set forth. It is preferred that the container be made of material of low thermal conductivity. Suitable material would be apparent to one skilled in the art and familiar with the invention. Similarly the heat sink heat exchanger, cooler, conduits connecting the components of the system, and the pumps as indicated are standard in the art and would be apparent to one familiar with this invention.

The inlet and outlet thermal exchangers extend across the inlet and outlet passages, respectively, passing in airtight fashion through the container and providing thermal communication from and to said thermal pump. Gas in the inlet and outlet passages may pass the inlet and outlet thermal exchangers substantially freely in heat-exchange relation.

The inlet and outlet thermal exchangers may be of widely varying types. Any thermal exchanger which may be used to transfer heat from one fluid to another is suitable. Tubes with fins are preferred. It is preferred that fins be made of a highly thermal-conducting porous metal. Sintered stainless steel 60% dense is especially preferred. Copper surfaces are also preferred. The use of a porous type metal will promote thermal exchange between the contained gas and the inlet and outlet thermal exchangers.

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The thermal pump and process of this invention may be used in many different applications requiring movement of gases. Its advantages, as aforementioned, are not limited to any particular application. The pump and process may be used for wide varieties of refrigeration applications including air-conditioning. Thus the heat load of FIG. 2 would come from air in the space to be cooled. The thermal pump and process may also be used in many chemical processes. This invention may be used in moving very low temperature gases. There is particular advantage possible in this area because large thermal gradients are more easily attainable. Numerous other specific applications would be apparent to one skilled in the art and familiar with this invention.

EXAMPLE

The cooling system of FIG. 2 is used, the gas being Freon 22 and the permeable membrane being natural rubber latex. The heat load is a room having a temperature of 70° F. The atmosphere outside the room serves as the heat sink. It has a temperature of 95° F. The pressures and temperatures of the gas at various points of flow in the system at steady state are represented in the chart below. The point letters are in reference to FIG. 2.

Point:	Pressure (p.s.i.a.)	Temperature (° F.)
A-----	83.7	115
B-----	277.2	300
C-----	277.2	120
D-----	277.2	90
E-----	83.7	40
F-----	83.7	40

The thermal pump in this system replaces the compressor or absorber and generator in cooling systems from the prior art. The apparatus and process, as shown in this example, provide a suitable cooling system.

While in the foregoing specification this invention has been described in relation to certain preferred embodiments thereof, and many details have been set forth for purpose of illustration, it will be apparent to those skilled in the art that the invention is susceptible to additional embodiments and that certain of the details described herein can be varied considerably without departing from the basic principles of the invention.

I claim:

1. A process for the thermal pumping of gas comprising the steps of
 - passing a low pressure and low temperature gas in heat-exchange relation to an inlet thermal exchanger, said inlet thermal exchanger cooling said gas and a membrane first face of a non-porous permeable membrane,
 - contacting said gas with said permeable membrane at said membrane first face, said gas being capable of solution in said permeable membrane and said membrane not permitting substantial passage of gas there-through except by means of solution,
 - passing said gas through said permeable membrane by solution of said gas into solution with said permeable membrane at said membrane first face, movement of said dissolved gas within said permeable membrane to a membrane second face of said permeable membrane and evaporation of said dissolved gas from said permeable membrane at said membrane second face upon heating of said membrane second

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face by an outlet thermal exchanger, said gas evaporated from said membrane second face having high pressure and high temperature, and said gas having lower solubility in said membrane at said high pressure and high temperature than at said low pressure and low temperature, and

passing said gas in heat-exchange relation to said outlet thermal exchanger, said outlet thermal exchanger heating said gas.

2. The process of claim 1 wherein said permeable membrane is of one material.

3. The process of claim 1 wherein said permeable membrane has several membrane layers.

4. The process of claim 1 wherein said gas is Freon 22 and said permeable membrane is natural rubber latex.

5. The process of claim 1 wherein said gas is Freon 22.

6. The process of claim 1 wherein said gas is a Freon.

7. The process of claim 1 wherein said permeable membrane is natural rubber latex.

8. A thermal pump comprising a container defining a passageway, said passageway being divided by a non-porous permeable membrane extending thereacross, said container and said permeable membrane defining an inlet passage and an outlet passage such that a gas may not freely flow from one passage to the other, said permeable membrane permitting substantial passage of gas there-through only by means of solution, said permeable membrane having a membrane first face and a membrane second face, an inlet thermal exchanger being proximate to said membrane first face, an outlet thermal exchanger being proximate to said membrane second face, said thermal exchangers providing thermal communication from and to said thermal pump.

9. The thermal pump of claim 8, said non-porous permeable membrane being supported by a first porous structure, said first porous structure having a first porous structure second face against said membrane first face of said permeable membrane and providing support for said permeable membrane, and a second porous structure, said second porous structure having a second porous structure first face against said membrane second face and providing support for said permeable membrane.

10. The thermal pump of claim 9 wherein said permeable membrane is of one material.

11. The thermal pump of claim 9 wherein said permeable membrane has several membrane layers.

12. The thermal pump of claim 9 wherein said gas is Freon 22 and said permeable membrane is natural rubber latex.

13. The thermal pump of claim 9 wherein said gas is Freon 22.

14. The thermal pump of claim 9 wherein said gas is a Freon.

15. The thermal pump of claim 9 wherein said permeable membrane is natural rubber latex.

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U.S. Cl. X.R.

62—115, 116, 467, 498; 417—53, 65, 207