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Heat pump apparatus and method for increasing the heat content of a fluid and thereafter transferring the heat content to an ambient atmosphere

The invention relates to a heat pump apparatus and a method used in combination with the heat pump for increasing the heat content of a fluid and thereafter transferring the heat content to an ambient atmosphere.

As is known, such a heat pump used to heat buildings, for example, includes an electrically-driven compressor, a throttle valve, an evaporator located in an ambient atmosphere outside the building, and a condenser within the building which discharges heat as a refrigerant is condensed. Such heat systems are therefore relatively complicated in structure, have low coefficients of performance based upon actual thermal conversion, and require liquid refrigerant which is expensive and might be toxic. Furthermore, the energy input into the pump system is usually electrical and, hence, does not utilize the heat rejected in the electrical energy production.

The attempts so far made to overcome these drawbacks have not yet been very successful, with the exception of the teaching given in the U.S. Patent 3,859,789 concerning a method and an apparatus for converting one form of energy into another with the use of a closed, continuous loop passageway containing a plurality of freely movable, mechanically unrestrained bodies which travel along the passageway in one direction only. The patent, however, does not teach, or in any way suggest, the use of heat exchanger means connected to the passageway at the end of the compression region to extract heat from the compressed fluid leaving the compression region. The heat exchanger means disclosed is used to supply heat to the gas exit from the passageway. There is no recognition that the device described in the patent could be modified so as to serve as a heat pump.

Based on certain principles as set forth in the cited patent, the invention as claimed is intended to remedy the known disadvantages by providing an improved, simplified, unidirectional energy converter heat pump apparatus and a method used in combination with the heat pump apparatus for increasing the heat content of a fluid at one location and thereafter transferring the heat content at an ambient temperature to another location so that the heat pump apparatus moves heat from a reservoir at a colder temperature (for example, the outdoor air or a waste heat stream) to a reservoir at a warmer temperature (for example, the outdoor air or a process heat stream), and use a natural heat source, and operate on cheap fluids.

This problem in accordance with the present invention is solved by the characterising clauses of the main claims.

The advantages offered by the invention are mainly that the heat pump apparatus provided can extract heat from compressed fluid leaving the compression region of the passageway, and that it can be used with a heat source such as natural gas, oil or coal, or a motor-driven compressor, and which can operate on cheap fluids such as air in contrast to the more expensive and toxic refrigerants used in conventional prior art heat pumps. At the same time, the heat pump of the invention is of relatively simple construction and has a high coefficient of performance. When used for cooling purposes, the reservoirs are simply reversed with the heat pump taking heat from the cooler indoors and exhausting it to the warmer outdoors as in a conventional air-conditioning system.

One way of carrying out the invention is described in detail below with reference to the drawings which illustrate only one specific embodiment, in which:

Fig. 1 is a schematic diagram of the unidirectional energy converter heat pump apparatus of the invention;

Fig. 2 is an illustration of an alternative form of unrestrained bodies which can be used in the heat pump apparatus of the invention;

Fig. 3 is a P—V diagram showing the thermodynamic cycle of the heat pump apparatus of Fig. 1;

Fig. 4 is a schematic diagram of the unidirectional energy converter heat pump apparatus of the invention shown in a cooling (i.e., air conditioning) mode;

Fig. 5 is an illustration of an embodiment of the invention employing two double unidirectional energy converters, one of which is used as an air compressor and the other of which is used as a heat pump;

Fig. 6 is a schematic diagram of a unidirectional energy converter forming a heat pump according to a further embodiment of the present invention; and

Fig. 7 is an illustration of a further form of an unrestrained body which is particularly useful in the embodiment of the invention shown in Fig. 6.

With reference to the drawings, and particularly to Fig. 1, the apparatus shown includes a closed, continuous loop passageway 10 defined by a housing having walls which are preferably smooth and formed from metal. Disposed within the continuous loop passageway 10 is a plurality of bodies 12, shown in the embodiment of Fig. 1 as solid spheroids. The tolerances or clearances between the surfaces of the bodies 12 and the inside walls of the continuous loop passageway 10 are such as to permit the bodies 12 to move freely along the continuous loop passageway 10. However, fluid flow past the bodies 12 within the continuous loop passageway 10 is substantially prevented. In the embodiment shown in Fig. 1, for example, the continuous loop passageway 10 has a circular cross section, but with other shaped bodies, other cross sections may be utilized including elliptical or polygonal cross sections. In some cases, it is advantageous to weld two bodies 12 together as shown in Fig. 2. The body 12A, comprising two bodies 12 welded at 13, has two circumferential lines of contact 15 and 17 with the inside walls of the continuous loop passageway 10. This arrangement does not impede the movement of the body, but increases the sealing effect between the body and the interior wall. At the same time, it decreases the chances of having the bodies 12 pit the interior wall surface of the continuous loop passageway 10 in those embodiments of the invention where a sharp bend occurs in the continuous passageway 10 and, further, reduces clearance problems due to deformations of the spheroids from impacts.

As shown in Fig. 1, the continuous loop passageway 10 is divided into sections. In an expander section, compressed air from a suitable compressor, not shown, enters the continuous loop passageway 10 through conduit 14. This causes successive ones of the bodies 12 to be propelled along the continuous loop passageway 10 in a counterclockwise direction as viewed in Fig. 1. That is, the compressed air from conduit 14 along with compressed air from heat exchanger 22, as described below, enters the continuous loop passageway 10 and expands adiabatically imparting kinetic energy in the form of increased forward velocity to each body 12 while the gas between successive ones of the bodies 12 is reduced in temperature. As the bodies 12 pass port means 16 connected to the continuous loop passageway 10, the cooler air which has been adiabatically expanded exits to the atmosphere and air from the ambient atmosphere enters the continuous loop passageway 12 through port means 18 and is thereafter compressed in a compression region of the continuous loop passageway 12. If a liquefiable vapor, rather than air, is used, or if for any other reason it is desired to maintain a closed system, the ports may be arranged and connected to conventional heat exchanger means (not shown) in any known manner. In an embodiment of the invention, a plurality of ports 16 and 18 is provided. The kinetic energy of the moving bodies is used to compress the gas entering at port 18, and the compressed gas exits from the continuous loop passageway 10 through conduit 20 connected to one side of a heat exchanger 22 via check valve 23. In the compression process, the temperature of the air is, of course, increased as well as its heat content. Part of the heat is extracted by means of the heat exchanger 22. The gas which passes through the heat exchanger 22 is then combined in conduit 14 with the compressed air from an external source (not shown) to propel the bodies 12 in the expander section.

Another preferred feature of the invention comprises latch means 21 located at or near the end of the compression region and adapted to prevent backward motion of the bodies in this region after their kinetic energy has been reduced. Any conventional latch means may be used, such as, for example, a spring-powered, bevelled latch 21 (spring not shown) operating in a manner similar to an ordinary door latch. That is, the latch projects slightly into the continuous loop passageway 10 and is bevelled in the direction of approach of the bodies 12 so that as each body 12 comes into contact with the latch means 21 in a counterclockwise direction it will depress the latch allowing it to pass, but the latch means 21 will not depress to allow the bodies 12 to retreat in a clockwise direction.

One possible thermodynamic cycle used in the heat pump of the invention is shown in Fig. 3 and is similar to a Brayton cycle. Between successive ones of the bodies 12 there is what can be termed a unit cell. Gas enters the expander section from conduit 14. The unit cell between successive bodies 12 in the expander section then seals off the inlet conduit 14 and adiabatically expands between points 2 and 1 in Fig. 3 to a pressure p_1 and volume V_1 at temperature T_1. For simplicity, it will be assumed that the pressure p_1 is atmospheric pressure. The velocity of the lead body 12 is now v_1, its maximum value.

The residual gas, whose temperature has been reduced to T_1 in the adiabatic expansion, is then purged through port means 16 and ambient air at a higher temperature enters through port means 18 and occupies the unit volume between successive bodies 12. Thus, heat is absorbed in this process from the cold reservoir (e.g., outdoor air). The actual volume between the bodies 12 remains essentially constant during this operation, but the specific volume increases to V_4 between points 1 and 4 in Fig. 3. In other words, less mass of gas enters the loop through port means 18 in each unit cell than was exhausted from the unit cells via port means 16. This difference in mass is made up by the additional air which enters the system from the external compressor via conduit 14.

The fresh charge of gas is then compressed between points 4 and 3 in Fig. 3 to volume V_3 at temperature T_3 and pressure p_2. The pressurized heated gas is then exhausted from the compressor section via conduit 20 through check valve 23, and heat is extracted through the heat exchanger means 22. The unit cell collapses and the cycle is then repeated, the total work being represented by the area within the lines between points 1, 2, 3 and 4 in Fig. 3.

The air-conditioning (i.e., cooling) mode of operation of the heat pump is shown in Fig. 4. The system is essentially the same as that of Fig. 1 and, accordingly, elements in Fig. 4 which correspond to those of Fig. 1 are identified by like reference numerals. In this case, port 16 corresponds to the cool air duct of an air-conditioning system; whereas port means 18 corresponds to the warm return. As an optional feature, heat exchanger means 17 may be connected to ports means 16 and 18, necessitating a slight rearrangement of these ports means 16 and 18 as shown. The heat exchanger means 22, in an air-conditioning system, will be located external to the building which is being cooled and would correspond to a conventional condensing coil in a refrigeration system. The same basic thermodynamic cycle shown in Fig. 3 is employed; however cycles other than the Brayton refrigeration cycle are also possible.

In the air-conditioning mode between points 2 and 1 in Fig. 3, the expander region takes air from the outdoor heat exchanger means 22 and adiabatically expands it to a temperature lower than the indoor temperature. The cooler air is exhausted into the indoors through exit port means 16; or it can be passed through an indoor heat exchanger means. Between points 1 and 4 of Fig. 3, the unit cell picks up a charge of warmer indoor air (Q_1). Between points 4 and 3, this warmer air is adiabatically compressed to a higher pressure and temperature; and between points 2 and 3, the heat is exhausted to the outdoors at constant pressure via the heat exchanger means 22 (Q_A). The net work to drive the cycle is provided by make-up air from an air compressor, not shown, passing into the expander section through conduit 14. The difference between the cooling and heating modes is, of course, that in the heating mode, heat is taken from outdoors and pumped indoors; whereas in the cooling mode, heat is taken from the indoors and pumped outdoors.

In Fig. 5, an embodiment of the invention is shown wherein unidirectional energy converters are employed both as the heat pump and as the air compressor designed to supply compressed air to the heat pump. In Fig. 5, the continuous loop passageway of the air compressor loop is indicated generally by the reference numeral 24 and the continuous loop passageway of the heat pump loop by the numeral 26. Each of the continuous loop passageways 24 and 26 incorporates two unidirectional energy converter heat pumps in series.

The air compressor loop 24 operates as follows. One portion of atmospheric air ($m_1 + m_2$) enters the lower leg 26 of the air compressor loop 24 at 28 via conduit 50 and then is compressed as the bodies 30 move upwardly in the lower leg 26. Part of the compressed gas exiting from the top of the lower leg 26, m_1, passes through a heat exchanger means 32 where heat is added from an external heat source Q_1. This source may, for example, comprise burning natural gas or any other suitable source of heat. The heated, compressed gas is used in an upper leg 34 of the air compressor loop 24 to propel the bodies 30 to the left by adiabatic expansion. After it has been adiabatically expanded, and reduced in temperature, in upper leg 34, the gas, m_1, exits at port means 36; while a new charge of atmospheric air ($m_1 + m_2$) enters at port means 38 where it is compressed by the propelled bodies 30 and exits at 40. Part of the compressed gas, m_1, is passed through a heat exchanger means 42 where heat is added, as described above, the resulting compressed and heated gas being reintroduced into the lower leg 26 at 44 where it adiabatically expands to propel the bodies 30 to the right. After it has been adiabatically expanded, and reduced in temperature, in the lower leg 26, the gas, m_1, exits at 37. The two portions ($2m_1$), comprising the adiabatically expanded gas, are then combined in conduit 52, with additional atmospheric air, $2(m_3-m_1)$, being added in conduit 55 to yield a quantity of gas of $2m_3$. One-half of this quantity, or m_3, then enters the input 56 and the remaining half, m_3, enters input 58, the respective inputs of the two compressor sections of the heat pump loop 26.

It will be noted that the two individual portions m_2 of the compressed and heated gas which exit from the air compressor loop 24 are passed through conduits 60 and 62, respectively, to the heat exchanger means 48 and 46, respectively, in the continuous loop passageway of the heat pump loop 26. In the heat pump loop 26 these two portions of gas m_2 are individually combined with the two respective compressed gas portions m_3 exiting from the two respective compressor sections at 66 and 64. The heat exchangers means 46 and 48 can be of the finned-tube type through which air is blown by means of a fan to heat the air within a building to a temperature much higher than the atmospheric air initially entering the system, the heat emanating from the heat exchangers being indicated by the arrows, Q'_1 in Fig. 5. The portion ($m_2 + m_3$) passing through the heat exchanger means 46 is again introduced into the heat pump loop 26 at 68 to propel the bodies 30 by adiabatic expansion and that portion ($m_2 + m_3$) passing through heat exchanger means 48 is fed back into the heat pump loop 26 at 70 to adiabatically expand and propel the bodies 30 forwardly in the lower leg of the heat pump loop 26. The two portions of adiabatically expanded gas, $2(m_2 + m_3)$, of reduced temperature are then exhausted through conduit 72 to the atmosphere; or can be passed through an additional heat exchanger located within a building when the system is used as an air-conditioning system. In the latter case, the heat exchanger means 46 and 48 will, of course, be located outside the building.

As the fluid is compressed by the bodies in the compressor sections, most of the kinetic energy of each body 30 is transferred to increase the enthalpy of the gas and to remove the gas from the compressor section under increased pressure. Similarly, as the fluid in the expander sections of the heat pump loop is adiabatically expanded between successive bodies 30 in the expander sections, the enthalpy of gas is decreased and energy is transferred to increase the kinetic energy of the bodies. The energy transferred in the various processes along the loop, of course, must be conserved so that at any time the total energy of a particular loop system is constant and the energy input and output is equal in steady-state operation.

The thermodynamics of the expander and compressor sections of the heat pump of the present invention can be analyzed from ideal considerations as undergoing isentropic processes. However, in actual operation, because of internal losses to the working fluid, the processes are not precisely isentropic. The processes take place, very nearly, as adiabatic processes, i.e., with no external heat losses, particularly when adequate and properly arranged insulation is attached to the outer walls of the continuous loop passageway 10, 24, 26 forming the expander and compressor sections. Thus, while isentropic operation might be assumed for the purpose of analysis, nevertheless the actual operating processes of the heat pump are better described as adiabatic.

In a similar fashion, the total external forces acting on the freely movable bodies 12, 30 as they move along the continuous loop passageway 10, 24, 26 must integrate to zero over time in one time period for a particular body to completely transit the loop system under steady-state operation. This is simply in accordance with Newton's second law of motion. Since the movable bodies 12, 30 will encounter friction forces opposing the direction of motion along the continuous loop passageway 10, 24, 26, these friction forces must be counterbalanced by some external force acting in the direction of motion. If the continuous loop passageway 10, 24, 26 along which the bodies 12, 30 travel is in a vertical, or near vertical, plane, such as shown, for example, in the embodiment of Figs. 1 and 5, the force of gravity can be used to provide at least part of the thrust to counterbalance the friction forces. If the loop passageway 10, 24, 26 must be in a horizontal plane, alternative external thruster forces may be applied to the bodies to counterbalance the friction forces. For example, mechanically-powered devices such as cams, sprocket wheels, or worm gears, or a linear magnetic motor may be used.

The number of bodies 12, 30 used in the heat pump apparatus of this invention, the length of the various regions (i.e., expander and compressor) of the continuous loop passageway 10, 24, 26 and the total length of the continuous closed-loop passageways 10, 24, 26 are constants for a particular heat pump design. This means that the control system of the compressor and heat pump loops must regulate the operating parameters to maintain approximately constant distribution of the bodies 12, 30 along the continuous loop passageway 10, 24, 26 for all operating levels.

As will be appreciated, the invention has great flexibility in design and performance in that it can be constructed in a continuum of sizes for heating or cooling capability. Furthermore, it can be constructed as a multiple-unit system in which various of the units can be turned ON or OFF as the load requires. This also aids reliability since if one of the units should fail, the system is still operable.

The system employs conduits, movable bodies, check valves, latches, and heat exchanger means which should contribute greatly to reliability and economy for home heating and cooling systems presently utilized in natural gas or oil heating.

It is also possible to use the invention in an arrangement in which the external compressor is replaced by a "pressurizer" which is an in-line component of the heat pump loop system between the compressor and expander regions. In this mode of operation, the apparatus would be designed to take in the same mass flow rate of gas as it exhausts in the vent-intake region, but consequently would compress to a lower pressure than required at the expander inlet. The role of the pressurizer, then, is to pressure the gas sufficiently to make up this difference using any known method for pressurizing. The energy input to the pressurizer is the energy source for running the heat pump, as will be understood.

In a typical installation, the overall length of the heat pump loop shown 26 in Fig. 5, for example, will be about thirty-four times the diameter of the bodies 30; while the overall length of the air compressor loop 24 will be about twenty-seven times the diameter of the bodies 30.

In Fig. 6, a further embodiment of the invention is shown wherein serially-arranged unidirectional energy converters form a heat pump. The heat pump uses a high pressure stage to convert heat energy into net mechanical energy which is then converted in a low pressure stage of the heat pump to heat energy. More specifically, the unidirectional energy converter heat pumps according to the embodiment shown in Fig. 6 is comprised of two heat engines and two heat pumps operating in parallel. A "racetrack" shaped tubular passageway extends within a vertical plane to form a continuous loop passageway 80 containing a plurality of bodies 81. The bodies 81 may be spheroids or other desired configuration but preferably the bodies 81 take the form as shown in Fig. 7, of hollowed members having a cylindrical configuration with spherical end surfaces. The leading end surface 82, in regard to the direction of travel by a body 81, is convex; whereas the trailing end 83 of the body 81 is concave. Ring members 84 are located in recesses formed within the outer cylindrical surface of the body 81 adjacent the convex end surface 82 and the concave end surface 83. The hollow bodies 81 provide the necessary design mass and permit greater flexibility to the selection of material for the construction of the bodies 81 independent of the mass required for operation. The ring members 84, which are lightly loaded, reduce losses to a minimum due to leakage of the fluid medium around the bodies 81. Also, the use of ring members places less stringent manufacturing tolerances for the production of the bodies 81. The bodies 81 move within the continuous loop passageway 80 and operate under light loads, particularly as compared to the loads imposed on the pistons of an internal combustion engine. The maximum velocity of the bodies 81 is typically the same as the velocity of pistons in an internal combustion engine. A thin film of oil such as, for example, SAE 20 or molybdenum disulfide dry powder, may be used, if desired, for lubrication between the bodies 81 and the racetrack since the fluid temperature does not exceed 816°C and usually does not exceed 649°C.

As is shown in Fig. 6, the continuous loop passageway 80 is divided into regions. In an expander region, hot compressed air enters the continuous loop passageway 80 through an entry port coupled to a conduit 85 whereby each body 81 is propelled, in succession, upwardly through the lower right quadrant of the continuous loop passageway 80. When a second body 81 passes the entry port for conduit 85, a portion of the hot air is closed off from the source, thus forming a unit cell of hot compressed air. The hot compressed air in the unit cell is expanded adiabatically until the leading body 81 passes a point in the continuous loop passageway 80 containing an entry port coupled with conduit line 86. As the leading body 81 passes this entry port, more compressed air at a lower entry temperature and pressure is fed into the unit cell between the body 81 from conduit line 86. The combined compressed air of the unit cell is further expanded adiabatically until the leading body 81 passes an exit port communicating with an exhaust manifold 87 in a vent region. The region of the racetrack between the entrance port for conduit 85 and the exit port for the exhaust manifold 87 forms an expander region of the continuous loop passageway 80 wherein energy of the hot compressed air from conduits 85 and 86 is converted to kinetic energy of the bodies 81. The exhaust manifold 87 coextends with the vent region wherein cold air is purged from each unit cell between the bodies 81 in the continuous loop passageway 80 and replaced by fresh air fed through an entry port by a manifold 88 from the outside. The manifolds 87 and 88 in the vent section terminate at the beginning portion of a compression region where the fresh air in the unit cell between bodies 81 is compressed adiabatically by the kinetic energy of the bodies 81.

The compression region has two stages in series. The largest portion and first of the compression stages extends to a discharge port for a conduit 89. The largest portion of the air that is compressed between the bodies 81 is passed from the unit cell through conduit 89 into heat exchanger 90 where the compresed air is cooled by heat exchange with room air. From the heat exchanger, the cooled compressed air is reintroduced by conduit 89 into the continuous loop passageway 80 through a port in the second expander region where the air is further cooled adiabatically in a unit cell and exhausted to the atmosphere below atmospheric temperature.

Returning to the compressor region, the second stage thereof utilizes the remaining kinetic energy of the bodies 81 to further compress a small quantity of air remaining in the unit cell. The second stage of the compressor region terminates at a port for a conduit 91 to deliver the compressed air from the second stage into a combustion chamber 92 where the compressed air is heated and then fed by conduit 91 to reenter the continuous loop passageway 80 through a port at the entrance of the second expander region. Unit cells of air are formed between the bodies 81 after the bodies 81 are passed through a thruster section wherein their direction of travel is altered, and thereafter the bodies 81 pass downwardly along the continuous loop passageway 80. The downward path of travel by the bodies 81 is accompanied by the formation of unit cells therebetween while the bodies 81 pass along a second expander region, second vent region and second compression region that are essentially duplicates as far as function is concerned to the corresponding regions already described. The unit cells formed between the bodies 81 during their downward travel along the continuous loop passageway 80 are supplied with heated compressed air from conduit 91 and supplied with further quantities of compressed air from conduit 89. As the leading body 81 of a unit cell passes from the expander section and enters the vent section the hot compressed air is expanded adiabatically whereupon the heat energy of the air is conveted to kinetic energy of the bodies 81. The lower, successively-arranged vent region includes a manifold 93 wherein cold air is purged from the unit cell between bodies 81 while the space between the bodies is replenished with fresh air from outside.

As shown in Fig. 6, for convenience, manifolds 87 and 93 communicate with a common duct to exhaust the cold air to the atmosphere. The temperature of the exhaust cold air is below atmospheric temperature. Below the vent region formed by manifold 93 is the second compression region consisting of two stages, the first of which terminates at an exit port for conduit 86 coupled to a heat exchanger 94 to exchange heat with room air.

The second stage of the compression region extends between the exit port for conduit 86 and an exit port for conduit 85. The remaining kinetic energy of the bodies 81 is utilized to further compress a small quantity of air remaining in the unit cell. The remaining air in the unit cell is fed by conduit 85 to a combustion chamber 95. Combustion chamber 95 functions in the same manner as combustion chamber 92 by reheating the heated compressed air for delivery by conduit 85 into the lower portion of the expander region to form a unit cell between bodies 81 for their upward travel along continuous loop passageway 80. Thus, in this manner the cycle is repeated with the bodies 81 traveling upwardly against the force of gravity along the vent and compressor regions at one side of the vertically-arranged continuous loop passageway 80. A parallelly-arranged heat engine and heat pump is formed by the expander, vent and compressor regions at the opposite vertical side of the continuous loop passageway 80 where the body 81 travels downwardly under the force of gravity. Thruster regions which take the form of U-shaped continuous loop passageway 80 sections feed the bodies 81 at the discharge side of the compression regions through the use of sprocket wheels or the like into the entry side of the expander regions. The thruster regions function to provide a net external force to the bodies 81 in their direction of motion around the passageway to equalize the forces due to friction which act to oppose the body motion.

It is apparent that the unidirectional continuous passageway loop 80 described is a compound heat engine and a heat pump, thermodynamically a double Brayton cycle. The high-pressure stages, i.e., the expander regions, convert heat energy into a net mechanical energy that drives the reverse Brayton cycle of a low-pressure stage, i.e., the compressor regions, as a heat pump. The compound heat engine and heat pump of this embodiment offers a system wherein the working fluid conveniently takes the form of air throughout the system, thus providing economy, simplicity and environmental cleanliness. The straight vertical portions of the passageway conduct the bodies 81 while traveling at their highest velocity, thus minimizing the forces and frictional losses that would otherwise adversely affect travel of the bodies 81. The porting of air or other fluid medium used in the system is performed preferably by the bodies 81, thus reducing the number and complexity of in-line valves for the conduit.

The thruster regions in the schematic illustration include means for conducting the body 81 along the U-shaped configuration of the continuous passageway loop 80 at the ends of the vertical portions thereof. While the U-shaped configuration to the continuous passageway loop 80 can be readily designed to utilize gravity to guide the bodies 81 along their reverse direction of travel, it is nevertheless preferred to provide means such as a sprocket wheel, a linear electromagnetic drive or a linear latch system to insure movement of the bodies 81 throughout the thruster regions. In Fig. 6, a sprocket wheel 96 is shown at both thruster regions to conduct the bodies 81 therealong. Each thruster wheel is coupled by a drive shaft to a pulley 97. The pulleys are interconnected by a timing belt 98. One of the pulleys 97 includes a second pulley section 99 coupled by a belt to a pulley on the output shaft of a suitable motor 100. This form of drive system provides synchronization between both sprocket wheels 96. The motor 100 is preferably a constant speed motor which may be coupled, as an alternative to a belt drive system, by a drive shaft through bevel gears on arbors for the sprocket wheel.

The heat exchangers 90 and 94 are typically counterflow air-to-air exchangers. Heat exchangers of known construction are capable of accommodating at the high temperature side at maximum temperatures of several hundred degrees C. The combustion chambers 92 and 95 may typically take the form of a chamber for the direct combustion of compressed natural gas with the working compressed air or, alternatively, a conventional gas-fired furnace may be utilized. Other conventional external heat sources may also be employed. However, when a direct combustion chamber is utilized, the heat of combustion is completely utilized by the heat pump and gases will be exhausted at subatmospheric temperatures. While, as described hereinbefore, the bodies form necessary valving at ports for the conduits, it may nevertheless be desirable to incorporate check valves at compressor outlets to minimize a backflow of air in part of the cycle. High frequency of response and low pressure drop characteristics are important criteria for selecting such check valves. Reed valves are suitable to form such check valves.

A back latch mechanism for the bodies may be conveniently used for start-up and shutdown operations of the heat engine and heat pump. At shutdown, it is necessary that the bodies come to rest and remain at predetermined positions so that they will be in the proper position for smooth start-up. This can be achieved by magnetically-operated latches which are actuated at shutdown and retract at start-up. Moveover, at start-up, an air compressor or accumulator may be utilized for the start-up operation.

A vertically-arranged continuous loop passageway 80 has been shown in Fig. 6 and described above solely for convenience of description. Other variations in the arrangement of the continuous loop passageway 80, including horizontal arrangement, are possible.

Claims

1. Heat pump apparatus characterised by

a) a continuous loop passageway (10, 24, 26, 80) containing a plurality of bodies (12, 30, 81) to move along the passageway,

b) means for generating a force by the expansion of a fluid in an expander region of said passageway (10, 24, 26, 80) to thereby propel successive ones of the bodies (12, 30, 81) in one direction along the passageway,

c) a compression region in the passageway beyond the expander region wherein fluid is compressed between successive ones of the propelled bodies (12, 30, 81),

d) port means (16, 18, 36, 38, 56, 88, 93) in the passageway (10, 24, 26, 80) between the expander region and the compression region to permit the venting of fluid which has been expanded in the expander region and the entrance of fluid which is to be compressed in the compression region,

e) a thruster region in the passageway (10, 24, 26, 80) beyond the compression region wherein a force is applied to successive ones of the bodies (12, 30, 81) to counterbalance the external forces acting against the bodies as they traverse the passageway (10, 24, 26, 80) and to return them from the end of the compression region to the beginning of the expander region, and

f) heat exchanger means (22, 42, 48, 90, 94) connected to the passageway (10, 24, 26, 80) at the end of the compression region to extract heat from the compressed fluid leaving the compression region.

2. The heat pump apparatus of claim 1 wherein said fluid entering said port means (16, 18, 36, 38, 56, 88, 93) comprises the ambient air external to a building, and said heat exchanger means (22, 42, 48, 90, 94) is disposed within the building.

3. The heat pump apparatus of claim 1 wherein each of said bodies (12, 30, 81) is of a shape that is substantially complementary to the cross-sectional shape of said continuous loop passageway (10, 24, 26, 80) so as to substantially seal the passageway (10, 24, 26, 80) from fluid around said bodies (12, 30, 81) and subdivide said fluid between said bodies (12, 30, 81) into separate units.

4. The heat pump apparatus of claim 1 wherein said continuous loop passageway (80) includes a first expander region, first port means (88), a first compression region, a first thruster region, and a first heat exchanger means (90), a second expander region, second port means (93), a second compression region, a second thruster region, and a second heat exchanger means (94), said first and second recited elements forming heat pumps connected in series in a single continuous loop passageway (80) containing said plurality of bodies (81).

5. The heat pump apparatus according to claim 1 or 3 wherein each of said bodies (12, 30, 81) has a hollow cylindrical shape, defining a body having a convex end surface (82) leading the body in its direction of travel and a concave end surface (83) trailing the body in its direction of travel and wherein said body includes spaced-apart ring members (84) to substantially seal the passageway (10, 24, 26, 80) from fluid flow around said body.

6. The heat pump apparatus of claim 1 wherein said heat exchanger means (22) has its exit connected to the passageway (10, 24, 26, 80) in the expander region to introduce fluid into the expander region from the heat exchanger means (22).

7. The heat pump apparatus of claim 6 including second heat exchanger means (17), and means for directing fluid from which heat has been extracted by expansion through said second heat exchanger means (17) to cool ambient atmosphere.

8. The heat pump apparatus of claim 1 wherein said means for generating a force comprises compressed gas from a compressor means, which gas is expanded in said expander region.

9. The heat pump apparatus of claim 8 wherein said compressor means comprises apparatus for adding heat to a given volume of said gas.

10. The heat pump apparatus of claim 8 wherein said compressor means comprises a second continuous loop passageway (24) containing a plurality of bodies (30) to move along said second passageway, means for generating a force by expansion of a gas in an expander region of said second passageway (24) to propel successive ones of the bodies (30) in one direction around the second passageway (24), a compression region in said second passageway (24) beyond the expander region wherein fluid is compressed between successive ones of the propelled bodies (30), port means (36, 38) in the second passageway between the end of the expander region and the beginning of the compression region to permit the venting of fluid which has been expanded and the entrance of fluid which is to be compressed, heat exchanger means (42) having its entrance connected to the second passageway (24) at the end of the compression region and its exit connected to the second passageway (24) at the beginning of the expander region, wherein heat is introduced into the portion of said compressed fluid traversing the heat exchanger (42) and the heated, compressed fluid is then introduced into the expander region, means to convey a portion of the compressed fluid from the end of the compression region of the second passageway (24) to the beginning of the expander region of the first passageway (26), and a thruster region in the second passageway (24) beyond the compression region wherein an external force is applied to successive ones of said bodies to counterbalance the external forces acting

against the bodies as they traverse the loop passageway and to return them from the end of the compression region to the beginning of the expander region.

11. The heat pump apparatus of claim 10 wherein said first-mentioned continuous loop passageway (26) includes at least two of said heat pumps connected in series, and wherein said second-mentioned passageway (24) includes at least two of said compressors connected in series, and wherein means are provided for conveying a portion of the compressed fluid from the end of the compression region of each compressor in the second passageway to the beginning of the expander region in an associated heat pump in the first-mentioned passageway (26).

12. The heat pump apparatus of claim 1 wherein said passageway (10, 24, 26, 80) is oriented such that the force acting on said bodies (12, 30, 81) in the thruster region is the force of gravity.

13. Method used in combination with a heat pump for increasing the heat content of a fluid and thereafter transferring the heat content to an ambient atmosphere, characterised by

a) providing a closed-continuous loop passageway (10, 24, 26, 80) containing a plurality of bodies (12, 30, 81) to move along the passageway,

b) generating a force between successive ones of said bodies (12, 30, 81) by the expansion of a fluid in an expander region of said passageway (10, 24, 26, 80) to increase the kinetic energy of the bodies (12, 30, 81) and thereby propel successive ones of the bodies (12, 30, 81) in one direction around the passageway (10, 24, 26, 80),

c) exiting said fluid after expansion thereof from the interior of said passageway (10, 24, 26, 80) at a reduced temperature,

d) introducing a fluid at a temperature higher than said reduced temperature into the interior of said passageway (10, 24, 26, 80) and thereafter compressing said introduced fluid between successive ones of the propelled bodies (12, 30, 81), and

e) thereafter passing the compressed fluid through heat exchanger means (22, 42, 48, 90, 94) connected to the passageway (10, 24, 26, 80) after compression of said fluid for extracting heat from the fluid thus compressed.

14. The method of claim 13 wherein the compressed fluid is passed through the heat exchanger means (22, 42, 48, 90, 94) being coupled to the passageway (10, 24, 26, 80) at the completion of compression of said fluid.

15. The method of claim 13 including the step of passing the compressed fluid after passage through said heat exchanger means (22, 42, 48, 90, 94) back into said passageway (10, 24, 26, 80) to propel successive ones of the bodies (12, 30, 81) in one direction along the passageway (10, 24, 26, 80).

16. The method of claim 13 wherein the steps of generating a force between successive ones of said bodies (12, 30, 81) until passing the compressed fluid through heat exchanger means (22, 42, 48) are repeated at least twice as said bodies (12, 30, 81) move around said continuous loop passageway (10, 24, 26, 80).

17. Heat pump apparatus characterised by

a) a continuous loop passageway (10, 24, 26, 80) containing a plurality of bodies (12, 30, 81) to move along said passageway, said continuous loop passageway (10, 24, 26, 80) including two vertical passageway sections (80) with successive ones of said bodies (12, 30, 81) moving upwardly against the force of gravity along one vertical section and thence downwardly under the force of gravity along the other vertical passageway section,

b) means for generating a force by the expansion of a fluid in an expander region in each of said two vertical passageway sections to thereby propel successive ones of the bodies (12, 30, 81) in one direction along the passageway,

c) a compression region in each of said two vertical passageway sections (80) beyond the expander region thereof to compress fluid between successive ones of the propelled bodies (12, 30, 81).

d) port means (16, 18, 36, 38, 56, 88, 93) in the passageway (10, 24, 26, 80) between the end of the expander region and the beginning of the compression region there-beyond to permit the venting of fluid which has been expanded in the expander region and the entrance of fluid which is to be compressed in the compression region,

e) a thruster region beyond each compression region in the passageway (10, 24, 26, 80) wherein a force is applied to successive ones of the bodies (12, 30, 81) to counterbalance the external forces acting against the bodies as they traverse the passageway (10, 24, 26, 80) and to feed them from the end of one compression region to the beginning of an expander region, and

f) heat exchanger means (32, 42, 48, 90, 94) connected to the passageway (10, 24, 26, 80) at the end of each compression region to extract heat from the compressed fluid leaving each compression region.

18. The heat pump apparatus of claim 17 wherein each thruster region includes a generally U-shaped section of passageway extending between said two vertical passageway sections to conduct successive ones of said bodies (12, 30, 81) from one vertical section to the other vertical section.

19. The heat pump apparatus of claim 18 wherein each thruster region further includes means to impart a net external force to successive ones of said bodies (12, 30, 81) while moving along each thruster region.

20. The heat pump apparatus according to claim 19 wherein said means to impart a net external force includes a sprocket wheel (96)

with members extending into said passageway to engage successive ones of said bodies (12, 30, 81) while moving along the thruster region, synchronizing drive means rotatably coupling together the sprocket wheels (96) at the thruster regions.

21. The heat pump apparatus of claim 1 further comprising means to prevent backward motion of said bodies (12, 30, 81) in the compression region of said continuous loop passageway (10, 24, 26, 80) after reducing the kinetic energy of the bodies (12, 30, 81).

22. The method of claims 13 or 14, comprising the further step of preventing backward motion of said bodies (12, 30, 81) in the compression region of said continuous loop passageway (10, 24, 26, 80) after reducing the kinetic energy of the bodies (12, 30, 81).

23. The method of claim 15 including the step of adding additional compressed fluid to the fluid passing through said heat exchanger means prior to introducing the mixture thereof into said passageway (10, 24, 26, 80) for expansion thereof.

Revendications

1. Appareil de pompe de chaleur caractérisé en ce qu'il comprend:

a) un passage en boucle continue (10, 24, 26, 80) contenant un certain nombre de corps (12, 30, 81) destinés à se déplacer le long de ce passage,

b) des moyens de production d'une force par détente d'un fluide dans une zone de détendeur du passage (10, 24, 26, 80), de manière à propulser un par un les corps successifs (12, 30, 81) dans un sens donné le long du passage,

c) une zone de compression située dans le passage au-delà de la zone de détendeur, et dans laquelle le fluide est comprimé entre les corps (12, 30, 81) ainsi propulsés,

d) des moyens d'orifices (16, 18, 36, 38, 56, 88, 93) disposés dans le passage (10, 24, 26, 80) entre la zone de détendeur et la zone de compression pour permettre l'échappement du fluide qui s'est détendu dans la zone de détendeur, et l'admission de fluide destiné à être comprimé dans la zone de compression,

e) une zone de poussée ménagée dans le passage (10, 24, 26, 80) au-delà de la zone de compression, et dans laquelle une force est appliquée aux corps (12, 30, 81) successifs pour compenser les forces extérieures agissant contre les corps lorsqu'ils circulent dans le passage (10, 24, 26, 80) et pour les ramener de l'extrémité de la zone de compression au début de la zone de détendeur, et

f) des moyens d'échangeurs de chaleur (22, 42, 48, 90, 94) reliés au passage (10, 24, 26, 80) à l'extrémité de la zone de compression pour extraire la chaleur du fluide comprimé quittant cette zone de compression.

2. Appareil de pompe de chaleur selon la revendication 1, caractérisé en ce que le fluide pénétrant par les orifices (16, 18, 36, 38, 56, 88, 93) est constitué par de l'air ambiant venant de l'extérieur d'un immeuble, et en ce que les moyens d'échangeur de chaleur sont placés à l'intérieur del'immeuble.

3. Appareil de pompe de chaleur selon la revendication 1, caractérisé en ce que chacun des corps (12, 30, 81) présente une forme sensiblement complémentaire de la section du passage en boucle continue (10, 24, 26, 80), de manière à assurer la fermeture étanche de ce passage (10, 24, 26, 80) par rapport au fluide entourant les corps (12, 30, 81) et à diviser en unités séparées ce fluide compris entre les corps (12, 30, 81).

4. Appareil de pompe de chaleur selon la revendication 1, caractérisé en ce que le passage en boucle continue (80) comprend une première zone de détendeur, des premiers moyens d'orifices (88), une première zone de compression, une première zone de poussée et un premier échangeur de chaleur (90), une seconde zone de détendeur, des seconds moyens d'orifices (93), une seconde zone de compression, une seconde zone de poussée et un second échangeur de chaleur (94), ce premier et ce second ensemble d'éléments cités ci-dessus formant des pompes de chaleur branchées en série dans un passage en boucle continue unique (80) contenant l'ensemble de corps (81).

5. Appareil de pompe de chaleur selon la revendication 1 ou la revendication 3, caractérisé en ce que chacun des corps (12, 30, 81) présente une forme cylindrique creuse définissant un corps muni d'une surface d'extrémité convexe (82) guidant ce corps dans son sens de mouvement et une surface d'extrémité concave (83) suivant le corps dans son sens de mouvement, et en ce que les corps comportent des éléments annulaires séparés (84) destinés à assurer une étanchéité parfaite du passage (10, 24, 26, 80) par rapport au débit de fluide entourant ce corps.

6. Appareil de pompe de chaleur selon la revendication 1, caractérisé en ce que la sortie de l'échangeur de chaleur (22) est reliée au passage (10, 24, 26, 80) de la zone de détendeur, de manière à introduire dans cette zone de détendeur le fluide venant de l'échangeur de chaleur (22).

7. Appareil de pompe de chaleur selon la revendication 6, caractérisé en ce qu'il comprend un second échangeur de chaleur (17) et des moyens destinés à faire passer dans ce second échangeur de chaleur (17) le fluide dont la chaleur a été extraite par détente, afin de refroidir l'atmosphère ambiante.

8. Appareil de pompe de chaleur selon la revendication 1, caractérisé en ce que les moyens de production de force sont constitués par du gaz comprimé, par un compresseur, ce gaz se détendant dans la zone de détendeur.

9. Appareil de pompe de chaleur selon la revendication 8, caractérisé en ce que le

compresseur comporte un appareil destiné à ajouter de la chaleur à un volume donné du gaz en question.

10. Appareil de pompe de chaleur selon la revendication 8, caractérisé en ce que le compresseur comporte un second passage en boucle continue (24) contenant un certain nombre de corps (30) destinés à se déplacer le long de ce second passage, des moyens de production d'une force par détente d'un gaz dans la zone de détente du second passage (24), de manière à propulser les corps (30) successifs dans une direction donnée suivant le second passage (24), une zone de compression située dans ce second passage (24) au-delà de la zone de détendeur, zone de compression dans laquelle le fluide est comprimé entre les corps (30) successifs propulsés les uns après les autres, des moyens d'orifices situés dans le second passage entre la fin de la zone de détendeur et le début de la zone de compression, de manière à permettre l'échappement du fluide qui sest détendu et l'admission du fluide destiné à être comprimé, un échangeur de chaleur (42) dont l'entrée est reliée au second passage (24) à la fin de sa zone de compression et dont la sortie est reliée au second passage (24) au début de sa zone de détente, la chaleur étant ainsi envoyée dans la partie du fluide comprimé traversant l'échangeur de chaleur (42), et le fluide comprimé chauffé étant ensuite envoyé dans la zone de détendeur, des moyens destinés à envoyer une partie du fluide comprimé de l'extrémité de la zone de compression du second passage (24) au début de la zone de détendeur du premier passage (26), et une zone de poussée située dans le second passage (24), au-delà de la zone de compression, zone de poussée dans laquelle une force extérieure est appliquée aux corps successifs pour équilibrer les forces extérieures agissant sur ces corps lorsqu'ils se déplacent dans le passage en boucle, et pour les ramener de la fin de la zone de compression au début de la zone de détendeur.

11. Appareil de pompe de chaleur selon la revendication 10, caractérisé en ce que le premier passage en boucle continue (26) mentionné ci-dessus, comprend au moins deux pompes de chaleur mortées en série, et en ce que le second passage (24) comprend au moins deux compresseurs montés en série, des moyens étant prévus pour faire passer une partie du fluide comprimé de la fin de la zone de compression de chaque compresseur du second passage au début de la zone de détendeur de la pompe de chaleur associée au premier passage (26).

12. Appareil de pompe de chaleur selon la revendication 1, caractérisé en ce que le passage (10, 24, 26, 80) est orienté de telle manière que la force agissant sur les corps (12, 30, 81) de la zone de poussée, soit la pesanteur.

13. Procédé utilizé en combinaison avec une pompe de chaleur pour augmenter la quantité de chaleur d'un fluide et transférer ensuite cette chaleur à l'atmosphère ambiante, procédé caractérisé en ce qu'il consiste à:

a) utiliser un passage en boucle fermée continue (10, 24, 26, 80) contenant un certain nombre de corps (12, 30, 81) destinés à se déplacer le long du passage,

b) produire une force entre corps (12, 30, 81) successifs par détente d'un fluide dans une zone de détente de ce passage (10, 24, 26, 80), pour augmenter l'énergie cinétique des corps (12, 30, 81) et propulser ainsi ces corps (12, 30, 81) successifs dans une direction donnée le long du passage (10, 24, 26, 80),

c) à évacuer ce fluide de l'intérieur du passage (10, 24, 26, 80) après détente et refroidissement de ce fluide,

d) introduire un fluide à température plus élevée que la température réduite ci-dessus, à l'intérieur du passage (10, 24, 26, 80) et, comprimer ensuite le fluide introduit entre corps propulsés successifs (12, 30, 81), et

e) faire passer ensuite le fluide comprimé dans l'échangeur de chaleur (22, 42, 48, 90, 94) relié au passage (10, 24, 26, 80), après compression du fluide, de manière à extraire la chaleur du fluide ainsi comprimé.

14. Procédé selon la revendication 13, caractérisé en ce que le fluide comprimé passe à travers l'échangeur de chaleur (22, 42, 48, 90, 94) couplé au passage (10, 24, 26, 80) à la fin de la compression du fluide.

15. Procédé selon la revendication 13, caractérisé en ce qu'il comprend l'étape consistant à faire repasser dans le passage (10, 24, 26, 80) le fluide comprimé après son passage dans l'échangeur de chaleur (22, 42, 48, 90, 94), de manière à propulser les corps successifs (12, 30, 81) dans un sens donné le long du passage (10, 24, 26, 80).

16. Procédé selon la revendication 13, caractérisé en ce que les étapes consistant à produire une force entre corps (12, 30, 81) successifs jusqu'à ce que le fluide comprimé ait traversé l'échangeur de chaleur (22, 42, 48), sont répétées au moins deux fois lorsque ces corps (12, 30, 81) se déplacent le long du passage en boucle continue (10, 24, 26, 80).

17. Appareil de pompe de chaleur caractérisé en ce qu'il comprend:

a) un passage en boucle continue (10, 24, 26, 80) contenant un certain nombre de corps (12, 30, 81) destinés à se déplacer le long de ce passage, le passage en boucle continue (10, 24, 26, 80) comprenant deux sections de passages verticaux (80) dans lesquelles les corps successifs (12, 30, 81) se déplacent vers le haut, contre l'effet de la pesanteur, le long d'une première section de passage vertical, puis ensuite vers le bas, sous l'action de la pensanteur, le long de l'autre section de passage vertical,

b) des moyens de production d'une force par détente d'un fluide dans une zone de détente de chacune des deux sections de passages verticaux, pour propulser ainsi les corps (12, 30, 81) successifs dans une direction donnée le long du passage,

c) une zone de compression située dans chacune des deux sections de passages verticaux (80), au-delà de leurs zones de détente, de manière à comprimer le fluide entre corps propulsés (12, 30, 81) successifs,

d) des moyens d'orifices (16, 18, 36, 38, 56, 88, 93) situés dans le passage (10, 24, 26, 80) entre la fin de la zone de détente et le début de la zone de compression située au-delà, de manière à permettre l'échappement du fluide qui s'est détendu dans la zone de détente, et l'admission du fluide qui doit être comprimé dans la zone de compression,

e) une zone de poussée située au-delà de chaque zone de compression du passage (10, 24, 26, 80), dans laquelle une force est appliquée aux corps (12, 30, 81) successifs pour équilibrer les forces extérieures agissant contre les corps lorsqu'ils se déplacent dans le passage (10, 24, 26, 80) et pour les faire passer de la fin d'une zone de compression au début d'une zone de détendeur, et

f) des moyens d'échangeurs de chaleur (32, 42, 48, 90, 94) reliés au passage (10, 24, 26, 80) à la fin de chaque zone de compression, de manière à extraire la chaleur du fluide comprimé quittant chaque zone de compression.

18. Appareil de pompe de chaleur selon la revendication 17, caractérisé en ce que chaque zone de poussée comprend une section de passage en forme générale, de U, comprise entre les deux sections de passages verticaux, de manière à conduire les corps (12, 30, 81) successifs de l'une à l'autre de ces deux sections de passages verticaux.

19. Appareil de pompe de chaleur selon l'une quelconque des revendications 17 et 18, caractérisé en ce que chaque zone de poussée comprend en outre des moyens permettant de communiquer une force extérieure nette à chacun des corps (12, 30, 81) successifs lorsqu'ils se déplacent le long de chaque zone de poussée.

20. Appareil de pompe de chaleur selon l'une quelconque des revendications 17 à 19, caractérisé en ce que les moyens destinés à fournir une force extérieure nette comprennent une roue dentée (96) munie d'éléments pénétrant dans le passage pour venir en prise avec les corps (12, 30, 81) successifs lorsqu'ils se déplacent le long de la zone de poussée, des moyens d'entraînement de synchronisation couplant ensemble les roues dentées (96) dans les zones de poussée.

21. Appareil de pompe de chaleur selon l'une quelconque des revendications 17 à 20, caractérisé en ce qu'il comprend en outre des moyens pour empêcher le retour en arrière des corps (12, 30, 81) dans la zone de compression du passage en boucle continue (10, 24, 26, 80) après diminution de l'énergie cinétique des corps (12, 30, 81).

22. Procédé selon l'une quelconque des revendications 13 et 14, caractérisé en ce qu'il comprend l'étape supplémentaire consistant à empêcher le mouvement de retour en arrière des corps (12, 30, 81) dans la zone de compression du passage en boucle continue (10, 24, 26, 80) après diminution de l'énergie cinétique des corps (12, 30, 81).

23. Procédé selon la revendication 15, caractérisé en ce qu'il comprend l'étape consistant à ajouter du fluide comprimé supplémentaire au fluide passant dans les moyens d'échangeur de chaleur avant d'introduire le mélange obtenu dans le passage (10, 24, 26, 80) pour obtenir la détente de ce fluide.

Patentansprüche

1. Wärmepumpe, gekennzeichnet durch

a) eine kontinuierliche Bahn (10, 24, 26, 80) mit einer Anzahl darin bewegter Körper (12, 30, 81),

b) eine Einrichtung zur Erzeugung einer Kraft durch Ausdehnung eines Fluids in einem Ausdehnungsbereich der Bahn (10, 24, 26, 80), um hierdurch aufeinanderfolgende Körper (12, 30, 81) in einer Richtung längs der Bahn anzutreiben,

c) einen Kompressionsbereich in der Bahn hinter dem Ausdehnungsbereich zur Komprimierung von Fluid zwischen aufeinanderfolgenden, angetriebenen Körpern (12, 30, 81).

d) Ausnehmungen (16, 18, 36, 38, 56, 88, 93) in der Bahn (10, 24, 26, 80) zwischen dem Ausdehnungs- und dem Kompressionsbereich, um die Abführung solchen Fluids zu ermöglichen, das im Ausdehungsbereich expandiert wurde, sowie die Zuführung von Fluid, das im Kompressionsbereich komprimiert wird,

e) einen Schubbereich in der Bahn (10, 24, 26, 80) hinter dem Kompressionsbereich zur Anlegung einer Kraft auf aufeinanderfolgende Körper (12, 30, 81) um die auf die Körper bei ihrem Durchgang durch die Bahn (10, 24, 26, 80) einwirkenden äußeren Kräfte auszugleichen und um sie vom Ende des Kompressionsbereichs zum Anfang des Ausdehnungsbereichs zurückzuführen, und

f) Wärmetauscher (22, 42, 48, 90, 94) die mit der Bahn (10, 24, 26, 80) im Bereich des Endes des Kompressionsbereichs verbunden sind, um Wärme von dem den Kompressionsbereich verlassenden Fluid abzuführen.

2. Wärmepumpe nach Anspruch 1, dadurch gekennzeichnet, daß das durch die Ausnehmungen (16, 18, 36, 38, 56, 88, 93) eintretende Fluid Umgebungsluft von außerhalb eines Gebäudes aufweist und daß die Wärmetauscher (22, 42, 48, 90, 94) innerhalb des Gebäudes vorgesehen ist.

3. Wärmepumpe nach Anspruch 1, dadurch gekennzeichnet, daß jeder der Körper (12, 30, 81) im wesentlichen komplementäre Ausbildung zur Querschnittsform der kontinuierlichen Bahn (10, 24, 26, 80) aufweist, um auf

diese Weise die Bahn (10, 24, 26, 80) gegenüber Fluid um die Körper (12, 30, 81) herum abzudichten und das Fluid zwischen den Körpern (12, 30, 81) in separate Einheiten zu unterteilen.

4. Wärmepumpe nach Anspruch 1, dadurch gekennzeichnet, daß die kontinuierliche Bahn (80) einen ersten Ausdehnungsbereich, eine erste Ausnehmung (88), einen ersten Kompressionsbereich, einen ersten Schubbereich und einen ersten Wärmetauscher (90), einen zweiten Expansionsbereich, eine zweite Ausnehmung (93), einen zweiten Kompressionsbereich, einen zweiten Schubbereich sowie einen zweiten Wärmeaustauscher (94) aufweist, wobei diese ersten und zweiten Elemente Wärmepumpen bilden, die in einer einzigen kontinuierlichen Bahn (80), welche die Körper (81) enthält, in Serie geschaltet sind.

5. Wärmepumpe nach Anspruch 1 oder 3, dadurch gekennzeichnet, daß die Körper (12, 30, 81) hohlzylindrisch ausgebildet sind und einen Körper mit einer konvexen Endfläche (82) bilden, die an der Vorderseite des Körpers bezüglich seiner Bewegungsrichtung liegt, sowie mit einer konkaven Endfläche (83) an der Körperrückseite bezüglich seiner Bewegungsrichtung und daß jeder Körper mit Abstand zueinander angeordnete Ringe (84) zur im wesentlichen vollständigen Abdichtung der Bahn (10, 24, 26, 80) gegen Fluidströmung längs des Körpers aufweist.

6. Wärmepumpe nach Anspruch 1, dadurch gekennzeichnet, daß der Ausgang des Wärmetauschers (22) im Ausdehnungsbereich mit der Bahn (10, 24, 26, 80) verbunden ist, um aus dem Wärmetauscher (22) in den Ausdehnungsbereich einzuführen.

7. Wärmepumpe nach Anspruch 6, dadurch gekennzeichnet, daß ein zweiter Wärmetauscher (17) vorgesehen ist, sowie eine Einrichtung zur Richtung solchen Fluids, dem Wärme durch Expansion durch den zweiten Wärmetauscher (17) zur Kühlung der Umgebungsatmosphäre entzogen wurde.

8. Wärmepumpe nach Anspruch 1, dadurch gekennzeichnet, daß die Einrichtung zur Erzeugung einer Kraft komprimiertes Gas aus einem Kompressor aufweist, welches im Expansionsbereich expandiert wurde.

9. Wärmepumpe nach Anspruch 8, dadurch gekennzeichnet, daß der Kompressor eine Vorrichtung zur Zuführung von Wärme zu einem gegebenen Volumen des Gases aufweist.

10. Wärmepumpe nach Anspruch 8, dadurch gekennzeichnet, daß der Kompressor aufweist eine zweite kontinuierliche Bahn (24) mit einer Anzahl von Körpern (30) zur Bewegung längs der zweiten Bahn, eine Einrichtung zur Erzeugung einer Kraft durch Ausdehnung eines Gases in einem Ausdehnungsbereich der zweiten Bahn (24), um aufeinanderfolgende Körper (30) in einer Richtung längs der zweiten Bahn (24) anzutreiben, einen Kompressionsbereich in der zweiten Bahn (24) hinter dem Expansionsbereich, zur Komprimierung von. Fluid zwischen aufeinanderfolgenden der angetriebenen Körper (30), Ausnehmungen (36, 38) in der zweiten Bahn zwischen dem Ende des Ausdehnungsbereichs und dem Anfang des Kompressionsbereichs zur Abführung von expandiertem Fluid und zur Zuführung von zu komprimierendem Fluid, Wärmetauscher (42), deren Einlaß mit der zweiten Bahn (24) am Ende des Kompressionsbereichs und deren Auslaß mit der zweiten Bahn (24) mit dem Anfang des Ausdehnungsbereichs verbunden sind, wobei Wärme in den den Wärmetauscher (42) durchlaufenden Teil des komprimierten Fluids zugeführt und das erhitzte, komprimierte Fluid dann in den Ausdehnungsbereich eingeführt wird, eine Einrichtung zum Transport eines Teils des komprimierten Fluids vom Ende des Kompressionsbereichs der zweiten Bahn (24) zum Anfang des Ausdehnungsbereichs der ersten Bahn (26), sowie einen Schubbereich in der zweiten Bahn (24) hinter dem Kompressionsbereich zum Anlegen einer äußeren Kraft an aufeinanderfolgende Körper, um die äußeren Kräfte auszugleichen, die gegen die Körper bei deren Durchlauf durch die Bahn wirken und um die Körper vom Ende des Kompressionsbereichs zum Anfang des Ausdehnungsbereichs zurückzuführen.

11. Wärmepumpe nach Anspruch 10, dadurch gekennzeichnet, daß die erste kontinuierliche Bahn (26) wenigstens zwei der Wärmepumpen, die in Serie geschaltet sind, aufweist, daß die zweite Bahn (24) wenigstens zwei der Kompressoren, die in Serie geschaltet sind, aufweist und daß Einrichtungen zum Transport eines Teils des komprimierten Fluids vom Ende des Kompressionsbereichs eines jeden Kompressors in der zweiten Bahn (24) zum Anfang des Ausdehnungsbereichs in einer zugeordneten Wärmepumpe in der ersten Bahn (26) vorgesehen sind.

12. Wärmepumpe nach Anspruch 1, dadurch gekennzeichnet, daß die Bahn (10, 24, 26, 80) derart angeordnet ist, daß die auf die Körper (12, 30, 81) wirkende Kraft im Schubbereich die Schwerkraft ist.

13. Verfahren zum Einsatz in Verbindung mit einer Wärmepumpe zum Anheben des Wärmeinhalts eines Fluids und anschließendem Überführen dieses Wärmeinhalts in eine Umgebungsatmosphäre, dadurch gekennzeichnet,

a) daß eine geschlossen — kontinuierliche Bahn (10, 24, 26, 80) mit einer Anzahl von Körpern (12, 30, 81) zur Bewegung längs der Bahn vorgesehen werden,

b) daß eine Kraft zwischen aufeinanderfolgenden Körpern (12, 30, 81) durch Ausdehnung eines Fluids in einem Ausdehnungsbereich der Bahn (10, 24, 26, 80) erzeugt wird, um die kinetische Energie dieser Körper (12, 30, (81) zu erhöhen und hierdurch aufeinanderfolgende Körper (12, 30, 81) in einer Richtung längs der Bahn (10, 24, 26, 80) anzutreiben,

c) daß das Fluid nach Ausdehnung aus dem

Inneren der Bahn (10, 24, 26, 80) bei verringerter Temperatur abgeführt wird,

d) daß ein Fluid mit höherer als der genannten verringerten Temperatur in das Innere der Bahn (10, 24, 26, 80) eingeführt und anschließend zwischen aufeinanderfolgenden der angetriebenen Körper (12, 30, 81) komprimiert wird und

e) daß danach das komprimierte Fluid durch mit der Bahn (10, 24, 26, 80) verbundene Wärmetauscher (22, 42, 48, 90, 94) geführt wird nach Kompression des Fluids zur Entziehung von Wärme aus dem so komprimierten Fluid.

14. Verfahren nach Anspruch 13, dadurch gekennzeichnet, daß das komprimierte Fluid im wesentlichen im Zeitpunkt des Abschlusses der Komprimierung durch mit der Bahn (10, 24, 26, 80) verbundene Wärmetauscher (22, 42, 48, 90, 94) geführt wird.

15. Verfahren nach Anspruch 13, dadurch gekennzeichnet, daß ein Schritt der Rückführung des komprimierten Fluids nach Durchtritt durch die Wärmetauscher (22, 42, 48, 90, 94) zurück in die Bahn (10, 24, 26, 80) vorgesehen ist, um aufeinanderfolgende Körper (12, 30, 81) in einer Richtung längs der Bahn (10, 24, 26, 80) anzutreiben.

16. Verfahren nach Anspruch 13, dadurch gekennzeichnet, daß die Schritte der Erzeugung einer Kraft zwischen aufeinanderfolgenden Körpern (12, 30, 81) bis zur Durchführung des komprimierten Fluids durch die Wärmetauscher (22, 42, 48) mindestens zweimal während des Durchlaufs der Körper (12, 30, 81) durch die kontinuierliche Bahn (10, 24, 26, 80) wiederholt werden.

17. Wärmepumpe, gekennzeichnet durch

a) eine kontinuierliche Bahn (10, 24, 26, 80) mit einer Anzahl von Körpern (12, 30, 81) zur Bewegung längs der Bahn, wobei diese zwei vertikale Bahnabschnitte (80) aufweist und aufeinanderfolgende Körper (12, 30, 81) sich längs eines vertikalen Bahnabschnitts gegen die Schwerkraft nach oben und dann in anderen vertikalen Bahnabschnitt unter Einfluß der Schwerkraft nach unten bewegen,

b) Einrichtungen zur Erzeugung einer Kraft durch Ausdehnung eines Fluids in einem Ausdehnungsbereich in jedem der beiden vertikalen Bahnabschnitte, um hierdurch aufeinanderfolgende Körper (12, 30, 81) in einer Richtung längs der Bahn anzutreiben,

c) einen Kompressionsbereich in jedem der beiden vertikalen Bahnabschnitte (80) hinter dem Ausdehnungsbereich, um Fluid zwischen aufeinanderfolgenden der angetriebenen Körper (12, 30, 81) zu komprimieren,

d) Ausnehmungen (16, 18, 36, 38, 56, 88, 93) in der Bahn (10, 24, 26, 80) zwischen dem Ende des Ausdehnungsbereichs und dem dahinter liegenden Beginn des Kompressionsbereichs, um die Abführung von im Ausdehnungsbereich expandiertem Fluid und die Zuführung von im Kompressionsbereich zu komprimierendem Fluid zu ermöglichen,

e) einen Schubbereich hinter jedem Kompressionsbereich in der Bahn (10, 24, 26, 80), wobei eine Kraft auf aufeinanderfolgende Körper (12, 30, 81) zum Ausgleich von auf die Körper bei deren Durchlauf durch die Bahn (10, 24, 26, 80) wirkenden äußeren Kräfte ausgeübt wird und um die Körper vom Ende eines Kompressionsbereichs zum Anfang eines Ausdehnungsbereichs zu führen,

f) im Bereich des Endes eines jeden Kompressionsbereichs mit der Bahn (10, 24, 26, 80) verbundene Wärmetauscher (32, 42, 48, 90, 94) zur Abführung von Wärme aus dem jeden Kompressionsbereich verlassenden komprimierten Fluid.

18. Wärmepumpe nach Anspruch 17, dadurch gekennzeichnet, daß jeder Schubbereich einen im wesentlichen U-förmigen Bahnabschnitt aufweist, der sich zwischen den beiden vertikalen Bahnabschnitten erstreckt, um aufeinanderfolgende Körper (12, 30, 81) vom einen zum anderen vertikalen Bahnabschnitt zu führen.

19. Wärmepumpe nach Anspruch 18, dadurch gekennzeichnet, daß jeder Schubbereich weiterhin eine Einrichtung zur Aufbringung einer Nettoaußenkraft auf aufeinanderfolgende Körper (12, 30, 81) während deren Durchlaufs durch jeden Schubbereich aufweist.

20. Wärmepumpe nach Anspruch 19, dadurch gekennzeichnet, daß die Einrichtung zur Aufbringung der Nettoaußenkraft ein Zackenrad (96) mit Gliedern aufweist, die sich in die Bahn zwecks Zusammenwirkens mit aufeinanderfolgenden Körpern (12, 30, 81) bei deren Durchlauf durch den Schubbereich erstrecken sowie synchronisierende Antriebseinrichtungen, die die Zackenräder (96) der Schubbereiche drehbar miteinander verbinden.

21. Wärmepumpe nach Anspruch 1, dadurch gekennzeichnet, daß eine Einrichtung zur Verhinderung einer Rückwärtsbewegung der Körper (12, 30, 81) im Kompressionsbereich der kontinuierlichen Bahn (10, 24, 26, 80) nach Verringerung der kinetischen Energie der Körper (12, 30, 81) vorgesehen ist.

22. Verfahren nach Anspruch 13 oder 14, dadurch gekennzeichnet, daß weiterhin der Schritt des Verhinderns einer Rückwärtsbewegung der Körper (12, 30, 81) im Kompressionsbereich der kontinuierlichen Bahn (10, 24, 26, 80) nach Verringerung der kinetischen Energie der Körper (12, 30, 81) durchgeführt wird.

23. Verfahren nach Anspruch 15, dadurch gekennzeichnet, daß der Schritt des Zufügens zusätzlichen komprimierten Fluids zum durch den Wärmetauscher durchtretenden Fluid vor dem Einführen dieser Mischung in die Bahn (10, 24, 26, 80) zur Ausdehnung derselben durchgeführt wird.

FIG. 1.

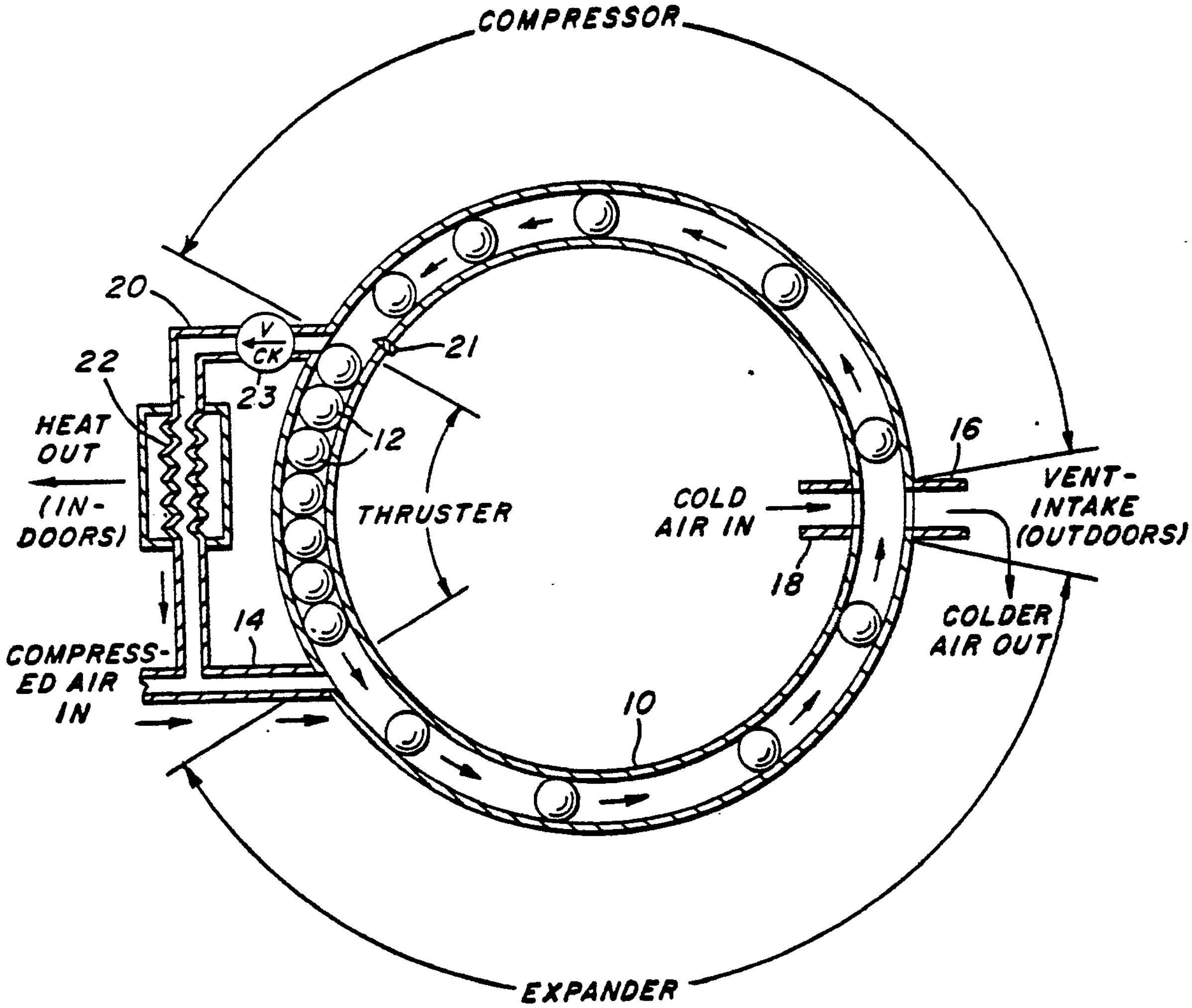


FIG. 2.

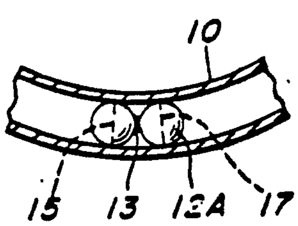


FIG. 3.

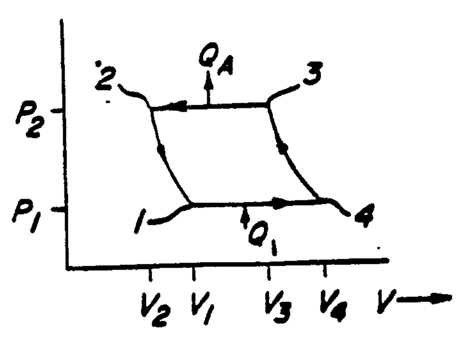


FIG. 4.

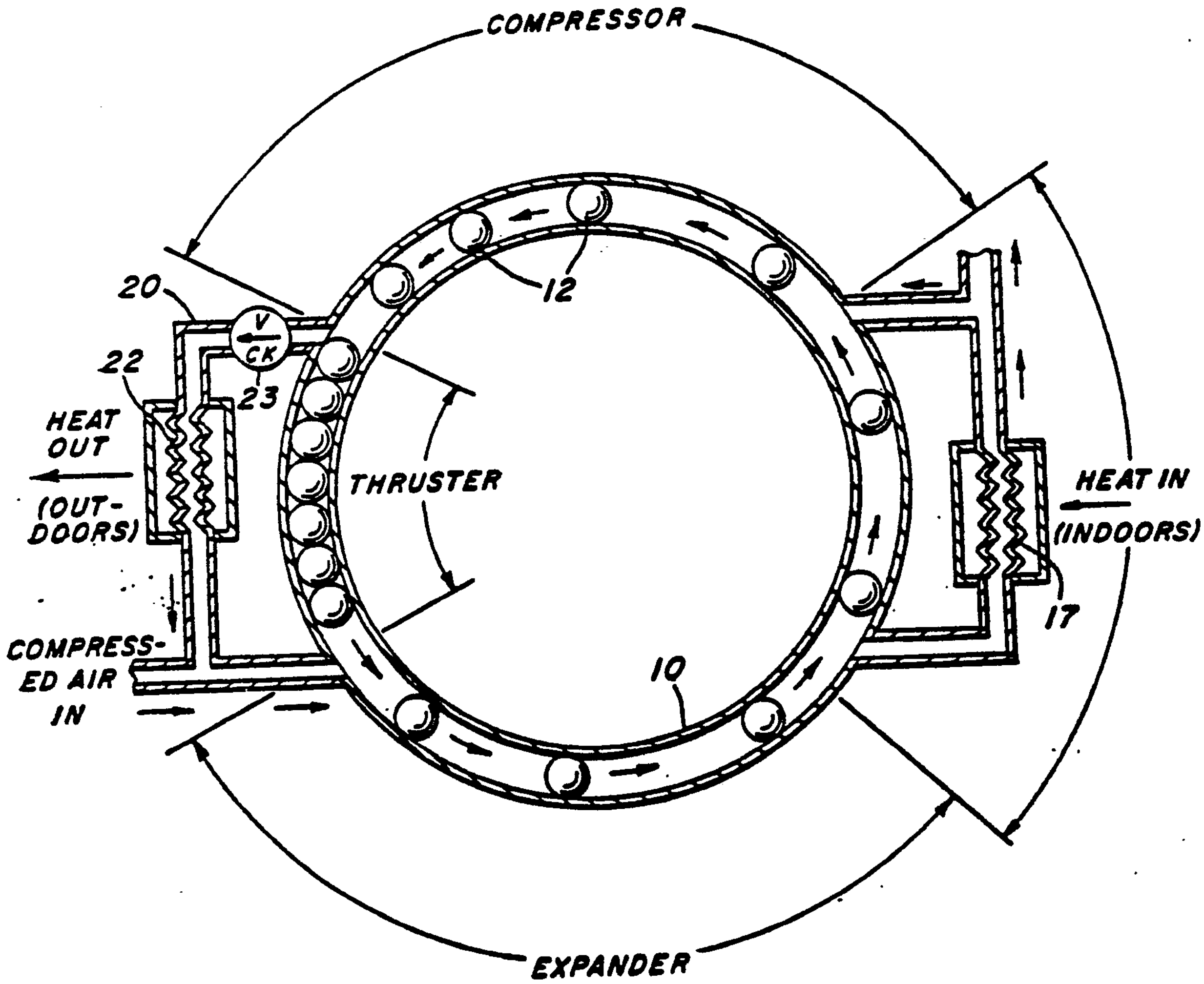

COMPRESSOR
20
12
V
CK
22
23
HEAT
OUT
(OUT-
DOORS)
THRUSTER
HEAT IN
(INDOORS)
17
COMPRESS-
ED AIR
IN
10
EXPANDER

FIG. 5.

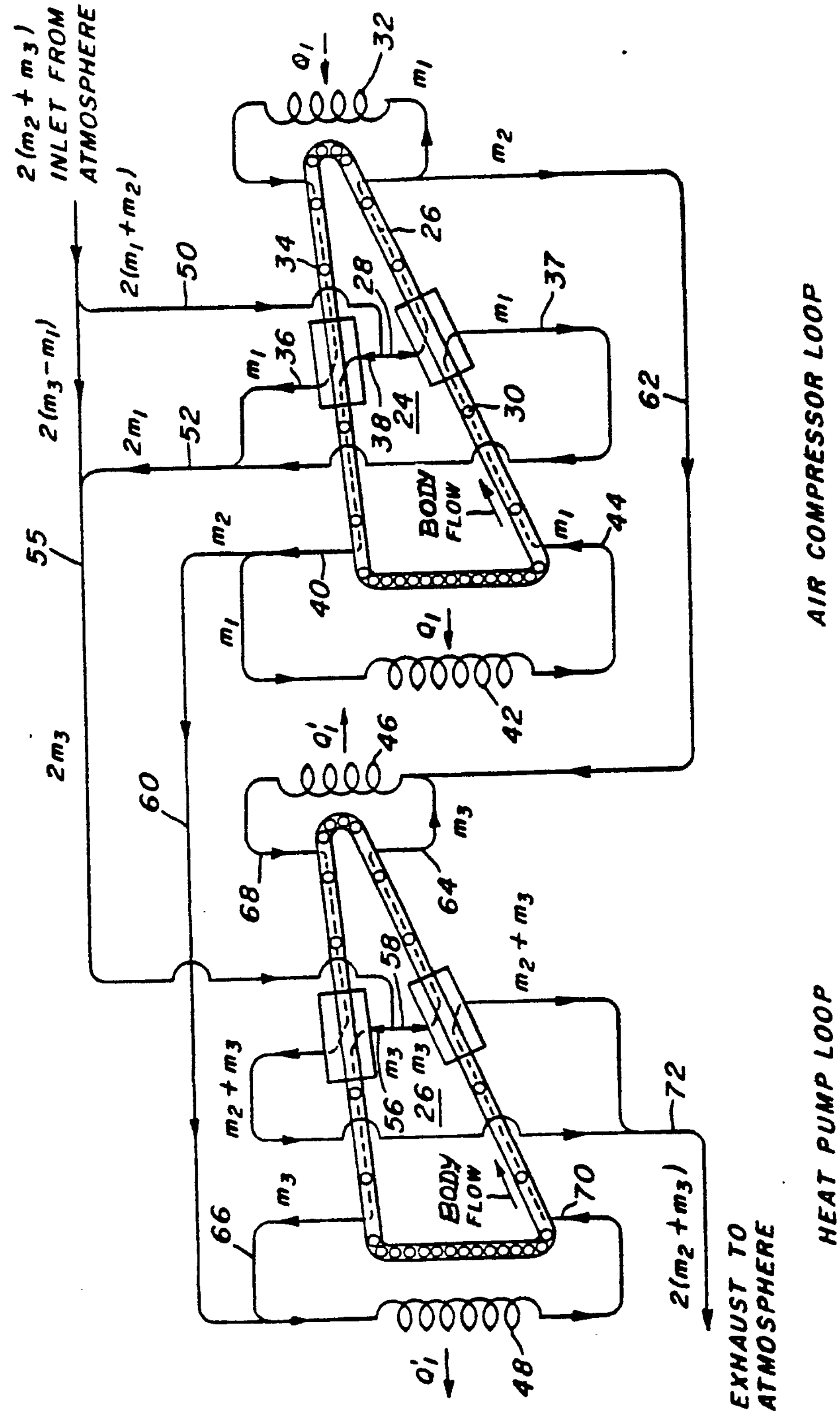

2(m2+m3)
INLET FROM
ATMOSPHERE
2(m1+m2)
2(m3-m1)
2m1
2m3
m1
m2
m3
m2+m3
Q1
Q'1
BODY
FLOW
AIR COMPRESSOR LOOP
HEAT PUMP LOOP
2(m2+m3)
EXHAUST TO
ATMOSPHERE

FIG. 6

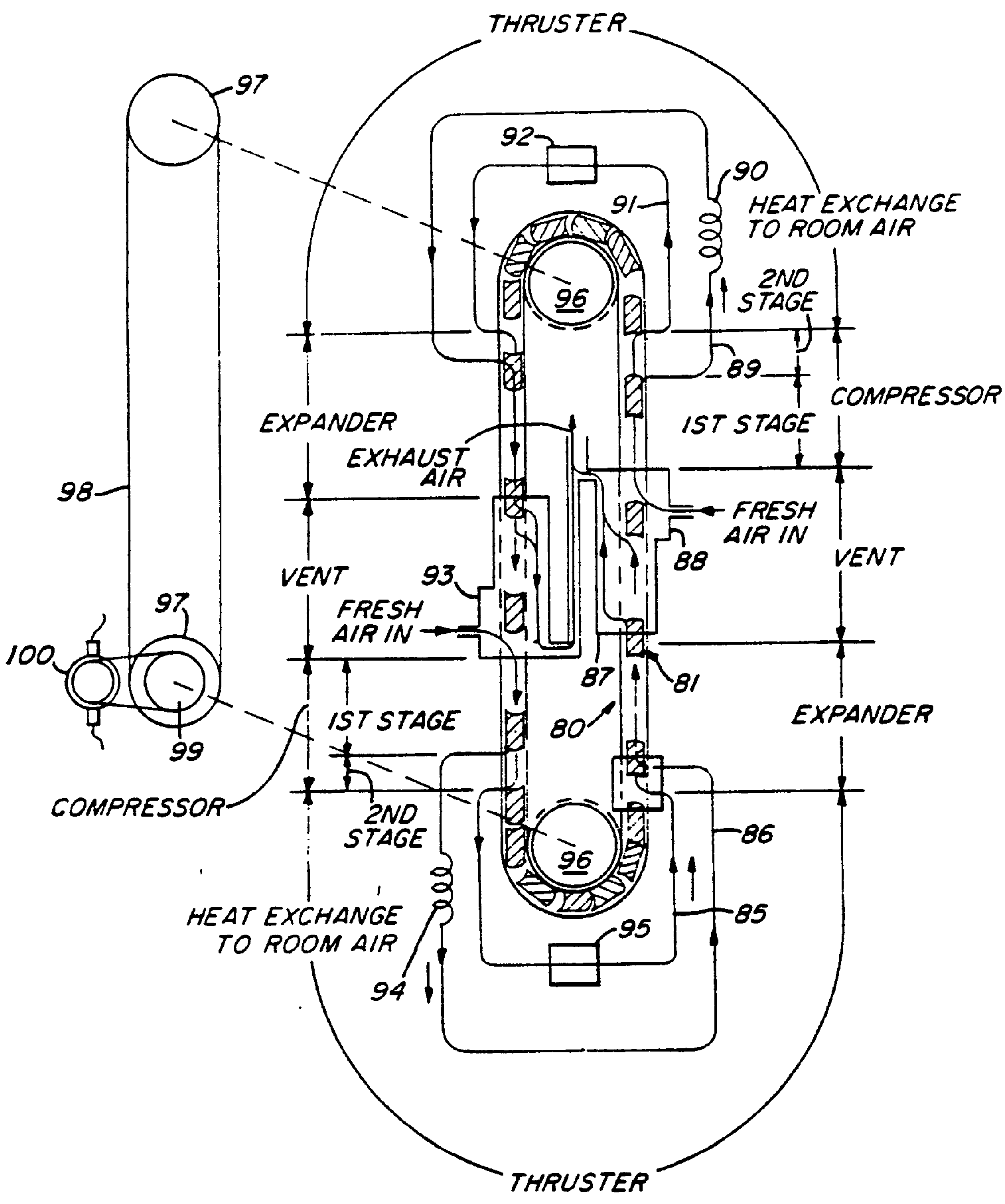
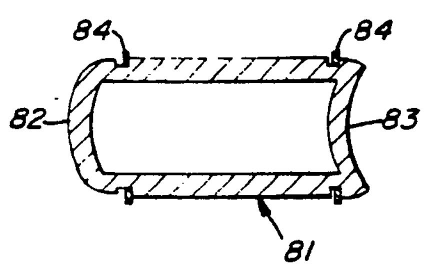

THRUSTER
97
92
90
91
HEAT EXCHANGE
TO ROOM AIR
96
2ND
STAGE
89
COMPRESSOR
EXPANDER
1ST STAGE
EXHAUST
AIR
98
FRESH
AIR IN
88
VENT
VENT
93
97
FRESH
AIR IN
100
87
81
1ST STAGE
80
EXPANDER
99
COMPRESSOR
2ND
STAGE
86
96
HEAT EXCHANGE
TO ROOM AIR
95
85
94
THRUSTER

FIG. 7


84
84
82
83
81