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(54) **HIGH EFFICIENCY THERMODYNAMIC SYSTEM**

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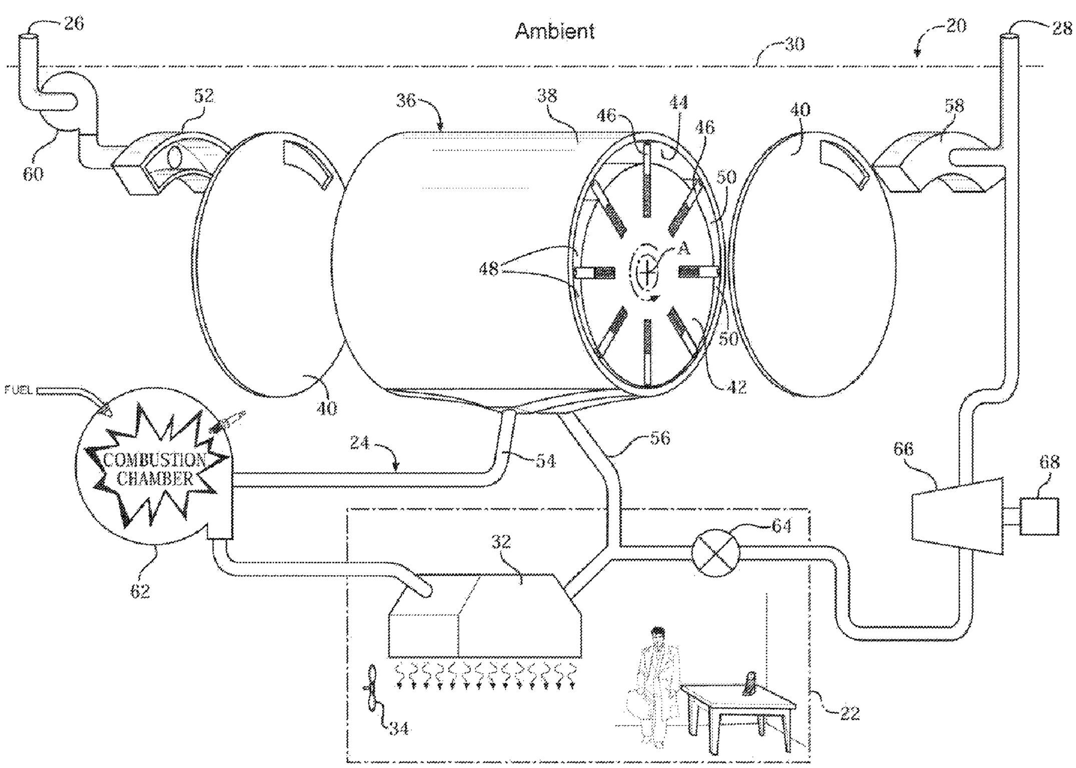
(57) **ABSTRACT**

An air-handling system selectively heats and/or cools a target space by circulating ambient air from the target space across a heat exchanger. The system operates along an air flow path having an inlet from the target space and an outlet back into the target space. Air-handling turbines or pumps are located near the inlet and outlet. The heat exchanger is placed in the flow path between the turbines or pumps. The heat exchanger transfers heat into or out of the air, causing a natural pressure increase or decrease in the air. The turbines or pumps are configured to harvest work from the induced pressure differential in order to conserve energy. A combustion chamber may be included directly in the flow path upstream of the heat exchanger for combusting a fuel in the air during a high heating mode.



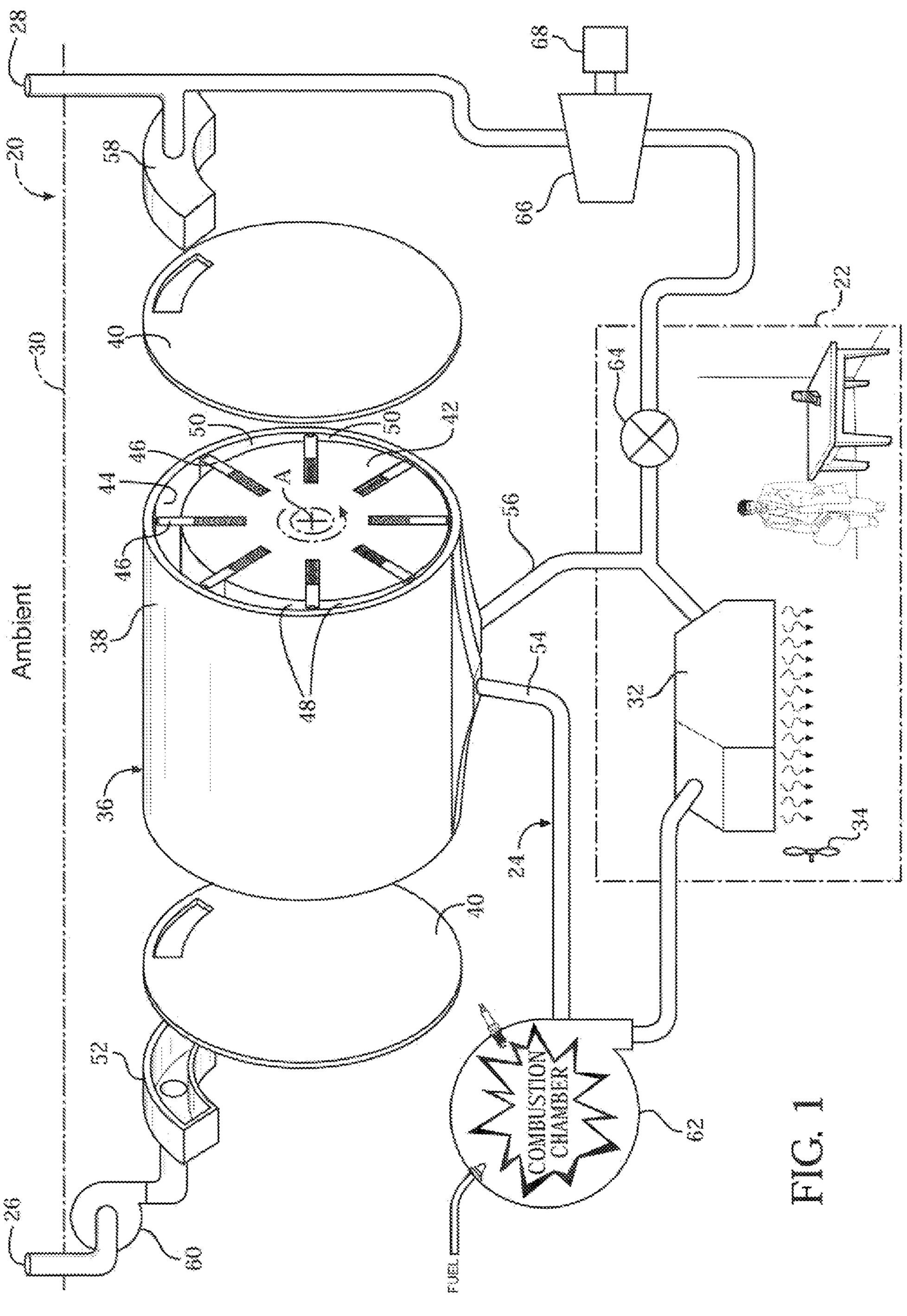

Ambient
COMBUSTION CHAMBER
FUEL
A
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
52
54
56
58
60
62
64
66
68

FIG. 1

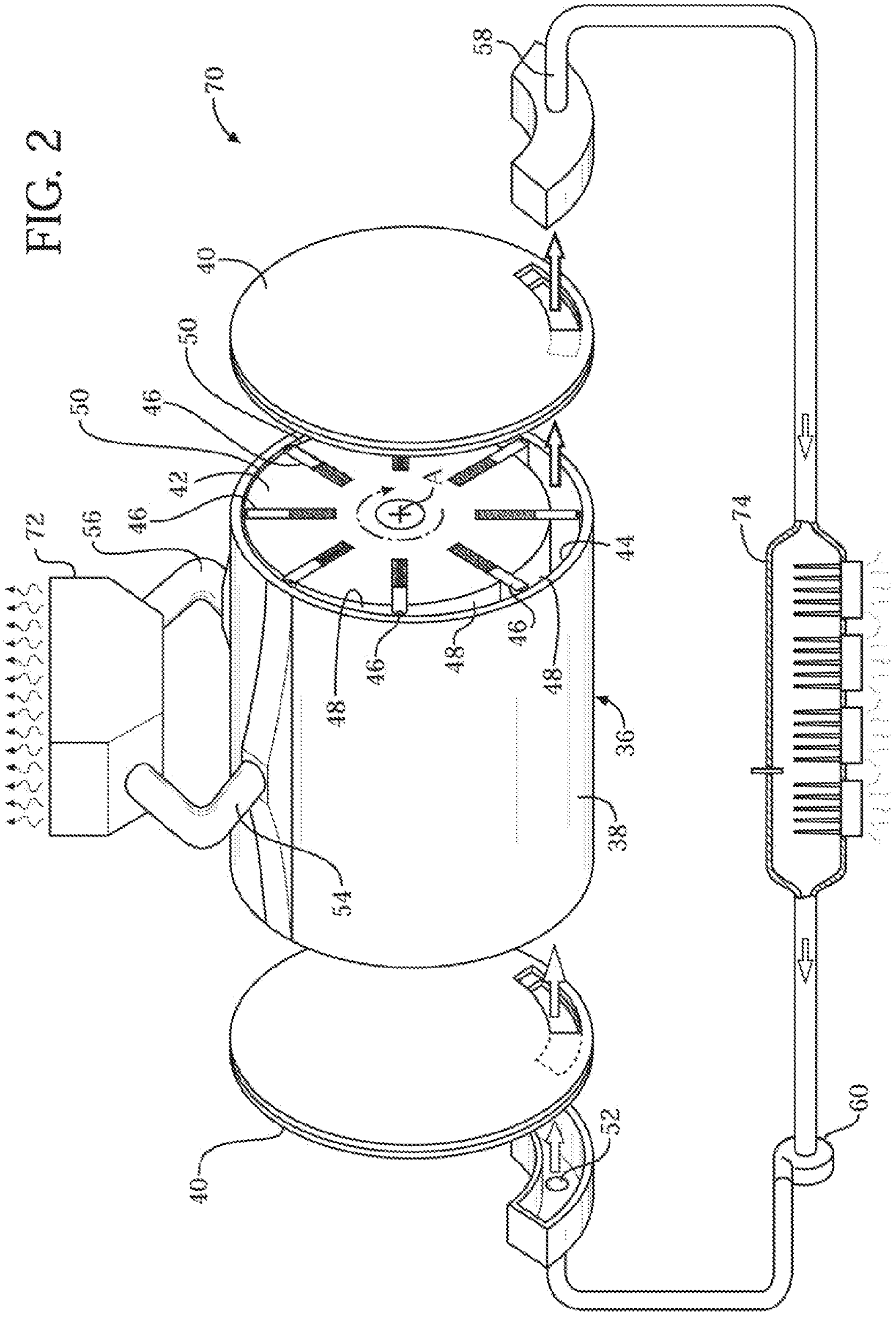


FIG. 2

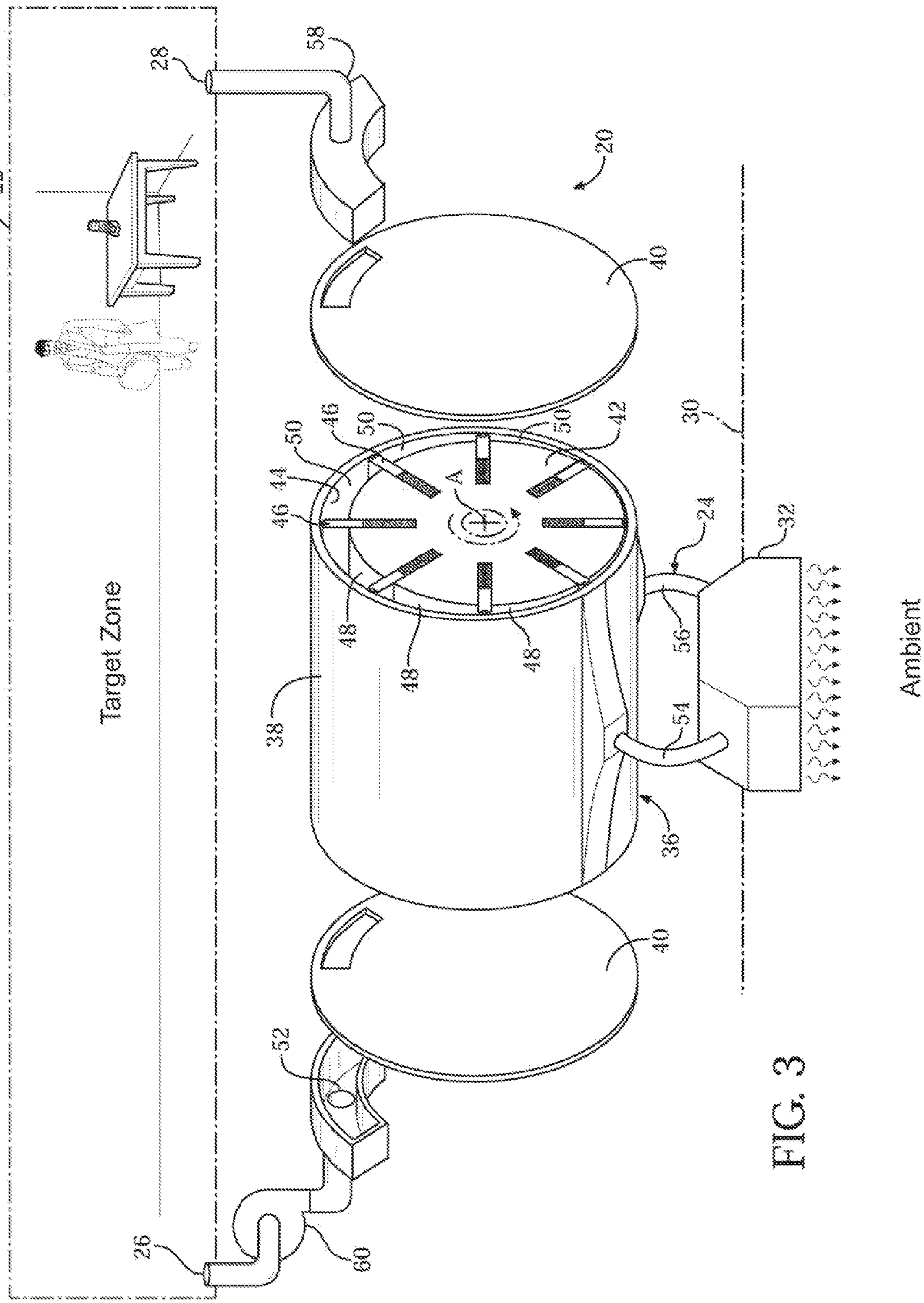

Target Zone
Ambient
22
20
28
58
26
60
52
40
40
38
36
24
32
30
42
44
46
46
48
48
48
48
50
50
50
54
56
A

FIG. 3

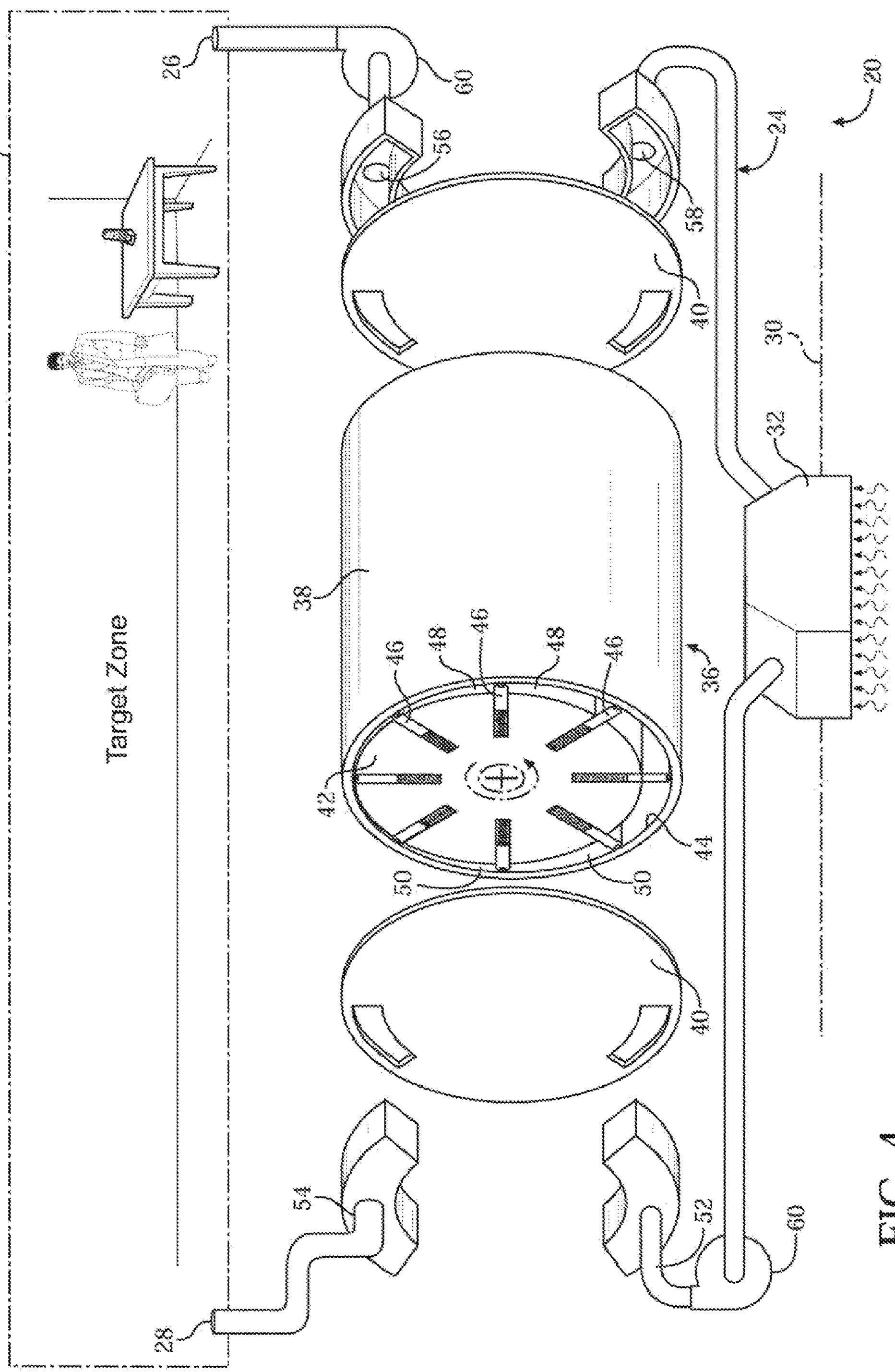
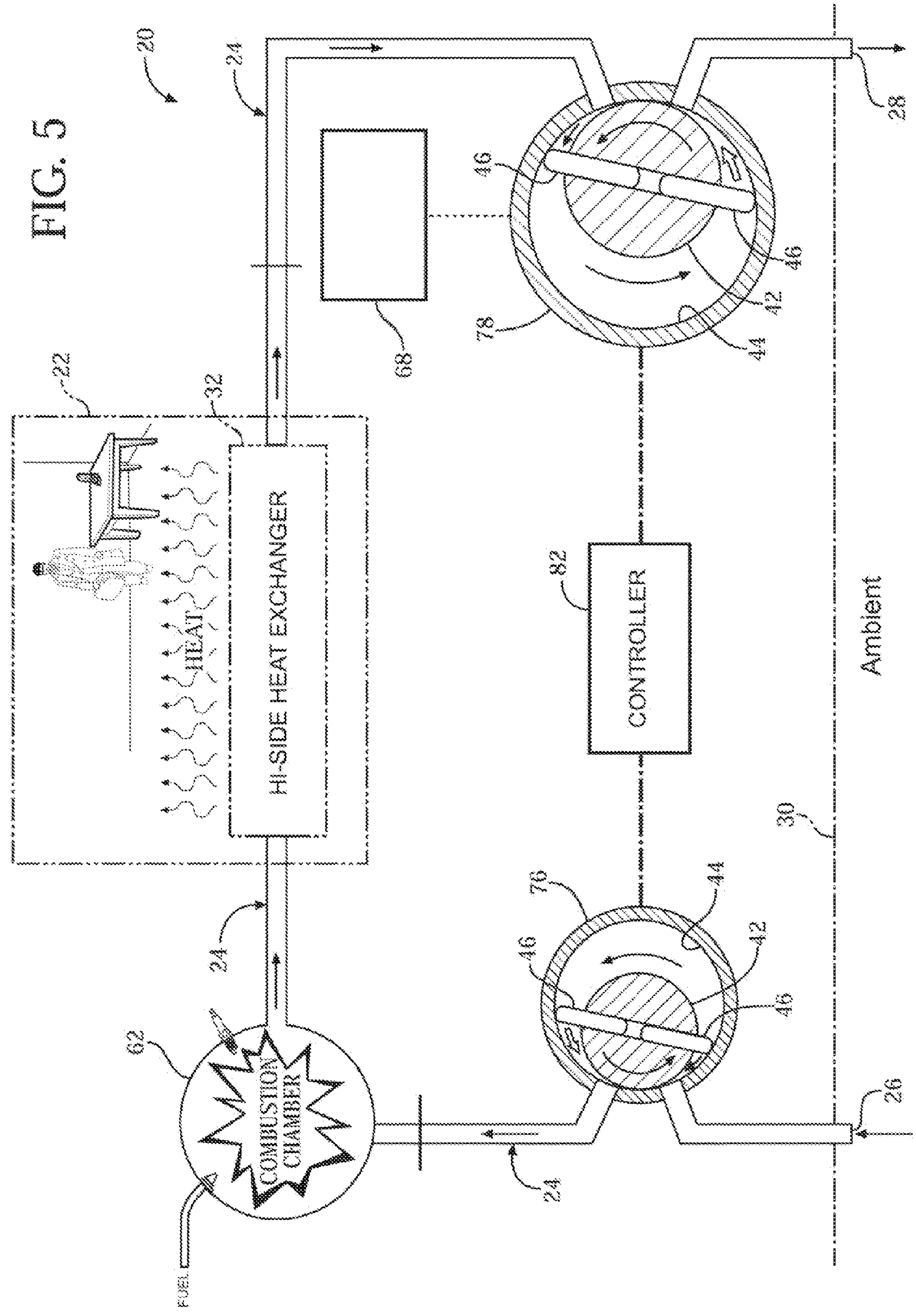

Target Zone
Ambient
20
22
24
26
28
30
32
36
38
40
42
44
46
48
50
52
54
56
58
60

FIG. 4

FIG. 5


20
24
22
32
HEAT
HI-SIDE HEAT EXCHANGER
68
78
46
46
42
44
28
82
CONTROLLER
Ambient
30
62
COMBUSTION CHAMBER
FUEL
24
24
76
46
42
44
46
26

HIGH EFFICIENCY THERMODYNAMIC SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a Continuation of U.S. Ser. No. 12/917,064 filed Nov. 1, 2010, now US 2011/0100011 published May 5, 2011, which claims priority to Provisional Patent Application No. 61/256,559 filed Oct. 30, 2009, the entire disclosures of which are hereby incorporated by reference and relied upon.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] A thermodynamic system for selectively heating and/or cooling a target space, and more particularly such a thermodynamic system in which ambient air comprises the working fluid therefor.

[0004] 2. Description of Related Art

[0005] Thermodynamic systems in the form of heat pumps are used in the prior art to alternatively heat or cool a target space in standard heating/cooling modes. Heat pumps generally include a compressor, two heat exchangers, and an expander all disposed in a common fluid flow path. Most heat pump systems are of the closed loop type in which the working fluid, typically a two-phase refrigerant, is circulated through the system so as to absorb heat through one of the heat exchangers and to reject heat from the other heat exchanger. When the target space is to be heated, the system is configured so that the heat exchanger that rejects heat will be stationed in the target space or in thermodynamic communication therewith such as via suitable plumping or ducting. Alternatively, when the target space is to be cooled, the system is configured so that the heat exchanger that rejects heat will be stationed in (or ducted to) the ambient environment or other suitable heat sink. Both configurations are considered within a standard heating/cooling mode. Not all heat pump systems are of the closed loop type; some heat pump systems have been proposed in an open-loop arrangement using ambient air as the working fluid.

[0006] A target space may be any enclosed or localized space. The target space may be a human environment, such as a building or the passenger compartment in an automobile. Alternatively, the target space may be a relatively small or large area for objects like a personal computer enclosure or a server room.

[0007] While such known heat pump systems are adequate in many climates, they are frequently unable to provide adequate heating during extremely cold conditions. This is because a typically sized system is not capable of cooling the working fluid (even in the case of a hazardous refrigerant) to a cold enough temperature so that it has capacity to absorb heat from an exceptionally cold ambient atmosphere. In these conditions, it may be necessary to supplement the heat pump with a secondary furnace, stove, or other heating apparatus to adequately heat the target space.

[0008] U.S. Pat. No. 3,686,893, issued to Thomas C. Edwards on Aug. 29, 1972 and U.S. Pat. No. 4,008,426, issued to Thomas C. Edwards on May 9, 1978 (hereinafter referred to as "the Edwards patents"), show a positive displacement rotating vane-type device that operates a thermodynamic cycle for simultaneously compressing and expanding a working fluid which may be air. The devices shown in the Edwards patents each have a stator housing and a rotor disposed in the stator housing defining an interstitial space therebetween. A plurality of vanes are operatively disposed between the rotor and the stator housing for dividing the interstitial space into revolving compression and expansion chambers. The vanes are spring loaded to slidably engage the inner wall of the stator housing. The rotor is rotatably disposed within the stator housing for rotating in a first direction. While the rotor is rotating, the vanes slide along the inner wall of the stator housing and simultaneously compress the working fluid in the compression chambers and expand the fluid in the expansion chambers.

[0009] The stator housing of the Edwards patents further define several ports for conducting the working fluid into and out of the device. These ports include a compression chamber inlet, a compression chamber outlet, an expansion chamber inlet, and an expansion chamber outlet. Additionally, the stator housing of the Edwards patents defines an expansion chamber inlet and an expansion chamber outlet. The compression chamber inlet and the expansion chamber outlet are both disposed on the side of the stator housing and communicate with different chambers. Thus, the working fluid enters and exits the device of the Edwards patents through various ports in a carefully arranged radial direction.

[0010] The Edwards patents are typical of prior art positive displacement rotating vane-type devices where the transfer of working fluid into and out of the device via ports is accomplished though localized piping that is arranged to prevent inadvertent mixing of high and low pressure fluids. Elaborate seals and other measures are sometimes taken to ensure the high and low pressure fluids never mix, and thereby reduce operating efficiencies. Such measures add considerably to the complexity and cost of positive displacement rotating vane-type devices.

[0011] There exists a need for further efficiency improvements in the field of heat pump systems, and more particularly for air-aspirated systems in which ambient air serves as the working fluid. There exists a need for a heat pump system that can fully meet the heating needs of a target space during very cold conditions. Furthermore, there exists a need for a heat pump system that is capable of efficiently transferring a working fluid (be it air or otherwise) between high and low pressure ports of a positive displacement rotating vane-type device without unnecessary complexity or cost.

BRIEF SUMMARY OF THE INVENTION

[0012] The invention comprises a high-efficiency air moving system for circulating ambient air in a target space across a heat exchanger. A confined flow path is established for routing ambient air as a working fluid from an inlet to an outlet. In this configuration, the inlet is disposed to receive ambient air from the target space as the working fluid and the outlet is disposed for expelling the air out of the flow path and back into the ambient air in the target space. A first turbine or pump is disposed in the flow path adjacent the inlet. The first turbine or pump is configured to control substantially all of the movement of air entering the flow path through the inlet. A second turbine or pump is disposed in the flow path adjacent the outlet. The second turbine or pump is configured to control substantially all of the movement of air exiting the flow path through the outlet. A heat exchanger is located in the flow path between the first and second turbines or pumps. The heat exchanger is configured to move heat into or out of the air in the flow path and thereby heat or cool the air in the target space when the air is subsequently discharged from the outlet. The addition or subtraction of heat in the flow path via the heat exchanger causes a corresponding pressure increase or pressure decrease, respectively, in the air between the first and second turbines or pumps relative to the ambient air. The improvement of this invention comprises at least one of the first turbine or pump and the second turbine or pump being configured to harvest work from the differentiated pressure of the air between the first and second turbines.

[0013] The system of the present invention enables a more efficient air moving system than air moving systems of the prior art because it utilizes at least two turbines or pumps on opposite sides (i.e., upstream and downstream) of a heat exchanger that are configured to reclaim available pressure energy from the working fluid caused by the addition or subtraction of heat. As a result, the system is more readily adapted to heat or cool a target space while concurrently conserving energy by harvesting at least some of the residual energy in the working fluid that exists in the form of a pressure differential above the ambient atmospheric conditions.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0014] These and other features and advantages of the present invention will become more readily appreciated when considered in connection with the following detailed description and appended drawings, wherein:

[0015] FIG. **1** is a view showing an air aspirated hybrid heat pump and heat engine system according to an embodiment of this invention;

[0016] FIG. **2** is a simplified, partially exploded view of a positive displacement rotating vane-type device as in FIG. **1** but configured in a closed-loop arrangement;

[0017] FIG. **3** shows an alternative embodiment of the invention wherein the positive displacement rotating vane-type device of FIG. **1** is configured in a cooling mode;

[0018] FIG. **4** is a view as in FIG. **3** but where the device is configured in a heating mode; and

[0019] FIG. **5** is yet another alternative embodiment of the air aspirated hybrid heat pump and heat engine system utilizing independent compressor and expander devices to achieve either a fixed or variable asymmetric compression/expansion ratio.

DETAILED DESCRIPTION OF THE INVENTION

[0020] Referring to the Figures, wherein like numerals indicate corresponding parts throughout the several views, one embodiment of the invention is shown in FIG. **1** as an open loop air aspirated hybrid heat pump and heat engine system **20** for selectively heating and cooling a target space **22**. The target space **22** can be an interior room in a building, the passenger compartment of an automobile, a computer enclosure, or any other localized space to be heated and/or cooled. The working fluid of the system **20** in this embodiment is most preferably air, however in general the principles of this invention will permit other substances to be used for the working fluid including multi-phase refrigerants in suitable closed-loop configurations.

[0021] The hybrid heat pump and heat engine system **20** includes a working fluid (e.g., air) flow path **24**, generally indicated in FIG. **1**, extending from an inlet **26** to an outlet **28**. The inlet **26** receives working fluid (air in this example) from an ambient source **30**, while the outlet **28** discharges air from the system **20** back to the ambient environment **30**. Preferably, the inlet **26** and outlet **28** are both disposed outside of the target space **22** and in the atmosphere **30** when atmospheric air is used as the working fluid.

[0022] A heat exchanger **32** is disposed in the flow path **24** between the inlet **26** and the outlet **28**. In the exemplary embodiment of FIG. **1**, the heat exchanger **32** is disposed in the target space **22** for transferring heat between the target space **22** and the working fluid in the flow path **24**. In a standard heating/cooling mode of operation, the system **20** is configured to either transfer heat from the working fluid to the target space **22** to heat the target space **22** or alternatively to transfer heat from the target space **22** to the working fluid to cool the target space **22**. The heat exchanger **32** is preferably a high efficiency heat exchanger **32** having a large surface area, such as by plurality of fins, for convectively transferring heat between air in the target space **22** and the working fluid in the flow path **24**. Preferably, a fan **34** or a blower is disposed adjacent to the heat exchanger **32** for propelling the air in the target space **22** through the heat exchanger **32** to assist in the heat exchange between the air in the target space **22** and the air in the heat exchanger **32**. Of course, conductive methods of heat transfer can also be used instead of or in addition to convective methods suggested by the fan **34** in the target space **22** in FIG. **1**.

[0023] In the exemplary embodiment of FIG. **1**, a positive displacement rotating vane-type device **36** is disposed in the flow path **24** for simultaneously compressing and expanding the air. While a positive displacement type device **36** is preferred for all implementations of this invention, some alternative embodiments of the invention as applied to the hybrid heat pump principles described below may substitute a blower that is not of the positive displacement variety in place of the positive displacement rotating vane-type device **36**. Such substitution is enabled by the heat pump principles of this invention which deal with what can be considered a very low pressure ratio Brayton Cycle. As such, those of skill in the art will appreciate that a common fan or blower could be effective at maintaining a suitable pressure differential, namely on the order of Atmospheric plus or minus 20-30%. Of course, efficiently losses would be expected to be greater with common fan or blower devices, but such may be acceptable in certain applications.

[0024] The vane-type device **36** includes a generally cylindrical stator housing **38** longitudinally between spaced and opposite ends **40**. A rotor **42** is disposed within the stator housing **38** and establishes an interstitial space **22** between the rotor **42** and the inner wall **44** of the stator housing **38**. A plurality of vanes **46** are operatively disposed between the rotor **42** and the stator housing **38** for dividing the interstitial space **22** into intermittent compression and expansion chambers **48**, **50**. The vanes **46** are spring loaded to slidably engage the inner wall **44** of the stator housing **38**. Accordingly, the plurality of compression **48** and expansion **50** chambers are each defined by a space between two adjacent vanes **46**. As the rotor **42** rotates relative to the stator housing **38**, the chambers **48**, **50** defined between adjacent vanes **46** sequentially and progressively transition between compression and expansion stages in a continuum so that the working fluid is simultaneously compressed in compression chambers and expanded in expansion chambers. That is to say, at any time during rotation of the rotor **42**, working fluid is being compressed in one portion of the device **36** and expanded in another portion of the device **36**.

[0025] Two arcuately spaced transition points correspond with maximum compression and maximum expansion of the working fluid. In the particular embodiment illustrated in FIG. 1, these transition points occur at the 12 o'clock and 6 o'clock positions of the stator housing 38, with the 12 o'clock position being the point of maximum expansion and the 6 o'clock position being the point of maximum compression. In alternative configurations of the rotary device 36, there may be only one transition point corresponding to either maximum compression or maximum expansion, such as in systems like that shown in FIG. 5 were the compression and expansion functions are carried out in separate devices. Or, there may be three or more transition points where a rotary device incorporates multiple lobes as shown for example in U.S. Pat. No. 7,556,015 to Staffend, issued Jul. 7, 2009, the entire disclosure of which is hereby incorporated by reference. In any case, therefore, the transition points may be defined as the rotary positions where the chambers 48, 50 between adjacent vanes 46 transition between the compression and expansion stages, respectively.

[0026] Working fluid ports are provided to move the working fluid into and out of the device 36. In the embodiment illustrated in FIG. 1, the ports include a compression chamber inlet 52, a compression chamber outlet 54, an expansion chamber inlet 56, and an expansion chamber outlet 58. The compression chamber inlet 52 and expansion chamber outlet 58 are located adjacent to the 12 o'clock position transition point corresponding to maximum expansion. By contrast, the expansion chamber inlet 56 and compression chamber outlet 54 are located adjacent to the 6 o'clock position transition point corresponding to maximum expansion. The compression chamber inlet 52 is in fluid communication with the inlet 26 for receiving the atmospheric air, and the expansion chamber outlet 58 is in fluid communication with the outlet 28 for discharging the air out of the flow path 24 to the atmosphere 30. The heat exchanger 32 is in fluid communication with the vane-type device 36 through the compression chamber outlet 54 and the expansion chamber inlet 56.

[0027] The compression chamber inlet 52 and the expansion chamber outlet 58 are generally longitudinally aligned with one another relative to the stator housing 38 for simultaneously communicating with the same chamber 48, 50. In other words, the compression chamber inlet 52 and the expansion chamber outlet 58 may be located on opposite longitudinal ends of the stator housing 38 so as to communicate simultaneously with a common chamber or chambers 48, 50. Thus a compression chamber port (inlet 52 in this example) and an expansion chamber port (outlet 58 in this example) are continuously in communication with at least one common chamber at or near a transition point. A pump 60 may be disposed in the flow path 24 between inlet 26 and the compression chamber inlet 52 for propelling the working fluid into the stator housing 38 through the compression chamber inlet 52. The arrangement of the ports according to this invention enable a greater fractional use of the swept volume of the rotating vane-type device. Furthermore, the flow of working fluid through the device 36 is improved.

[0028] The rotor 42 is rotatably disposed within the stator housing 38 for rotating in a first direction. While the rotor 42 is rotating, the vanes 46 slide along the inner wall 44 of the stator housing 38 and simultaneously reduce the volume of the compression chambers 48 and increase the volume of the expansion chambers 50. In the exemplary embodiment, vane-type device 36 accomplishes the simultaneous compression and expansion because the cross-section of the inner wall 44 of the stator housing 38 is circular and the rotor 42 rotates about an axis A that is off-set from the center of the circular inner wall 44. Alternatively, the stator housing 38 could be elliptically shaped and the rotor 42 could rotate about the center of the elliptical stator housing 38. Other configurations are of course possible, including those described in U.S. Pat. No. 7,556,015 as well as those described in priority document U.S. Provisional Application Ser. No. 61/256,559 filed Oct. 30, 2009, the entire disclosure of which is hereby incorporated by reference and relied upon.

[0029] The embodiment of FIG. 1 can operate in a standard heating/cooling mode or in an optional high heating mode. In the standard heating/cooling mode, the pump 60 propels atmospheric air into the vane-type device 36 through the compression chamber inlet 52. The temperature and pressure of the air both increase as the air is compressed in the compression chambers 48 before exiting the device 36 through the compression chamber outlet 54. The pressurized and warmed air flows passively through a dormant combustion chamber 62 and then to the heat exchanger 32 where it dispenses heat to warm the target space 22. Exiting the heat exchanger 32, the cooled but still pressurized air then flows back to the device 36 and enters the stator housing 38 via the expansion chamber inlet 56 at or near the 6 o'clock transition point. The air is directed into the next available expansion chamber 50 where is carried and swept in an expanding volume to depressurize, preferably back to the atmospheric pressure. Available pressure energy in the working fluid is thus released from the working fluid to act on the rotor 42 as a torque and thereby directly offset the energy required on the compression side of the rotor 42 working to simultaneously compress the working fluid in chambers 48.

[0030] Next, the air is pushed out of the vane-type device 36 through the expansion chamber outlet 58 by the air entering the vane-type device 36 through the compression chamber inlet 52. Finally, the air is discharged to the atmosphere 30 through the outlet 28. The difference in the pressure of the air entering the expansion chambers 50 and the atmospheric pressure represents potential energy. The expansion chambers 50 of the vane-type device 36 harness that potential energy and use it to provide power to the rotor 42.

[0031] The system includes a combustion chamber 62 in the flow path 24 between the compression chamber outlet 54 of the vane-type device 36 and the heat exchanger 32. During the standard heating/cooling mode, described above, the combustion chamber 62 remains dormant. However, during an optional high heating mode, a fuel introduced into the combustion chamber 62 is combusted, or burned, in the working fluid to greatly increase both its temperature and pressure within the flow path 24. The fuel may be any suitable type including for examples natural gas, propane, gasoline, methanol, grains, particulates or other combustible materials.

[0032] The compression chambers 48 of the vane-type device 36 compress the air by a first predetermined ratio, and the expansion chambers 50 of the vane-type device 36 expand the air by a second predetermined ratio. In the FIG. 1 embodiment, the first and second predetermined ratios are approximately equal to one another. When accounting for heat transfers and losses, the equal expansion/compression ratios are adequate to extract all available work energy from the fluid during the standard heating/cooling modes of operation. However, following the combustion of air in the combustion chamber 62 during the high heating mode, the pressure of the air in the flow path **24** is substantially elevated such that the vane-type device **36** cannot be expected to fully (or nearly fully) depressurize all of the air in the flow path **24** back to the atmospheric pressure. Therefore, a secondary expander **66** may be provided to receive surplus working fluid. The secondary expander **66** may be located downstream of a valve **64** disposed in a spur flow path adjoining the main flow path **24** extending between the heat exchanger **32** and the expansion chamber inlet **56**. During the standard heating/cooling mode, the valve **64** may be closed to direct all of the working fluid in the flow path **24** from the heat exchanger **32** to the expansion chamber inlet **56**. Although not shown, a pressure regulator may be included in the flow path **24** leading to the expansion chamber inlet **56**, and the valve **64** may operate in conjunction with the pressure regulator to open when the pressure regulator reaches a maximum pressure threshold. During the high heating mode when excesses of pressure are generated in the working fluid, the valve **64** is manipulated (either automatically or manually) to direct a portion of the working fluid from the heat exchanger **32** to a secondary expander **66**. The remaining portion of the working fluid travels to the expansion chamber inlet **56** as described above. Thus, in order to improve the energy efficiency of the system, it is advantageous to redirect at least some of the pressurized air from the heat exchanger **32** to the secondary expander **66**, which is mechanically connected to an energy receiving device, here an electric generator **68**, and there reclaimed. Preferably, all of the surplus working fluid, i.e., that portion of the working fluid that cannot be fully expanded to ambient pressure in the expansion chambers **50**, is directed to the secondary expander **66** where potential energy in the working fluid is converted into another useful form of energy. The vane-type device **36** and the electric generator **68** work together to capture and convert any residual pressure energy remaining in the working fluid before it is discharged to ambient **30**.

[0033] In operation, during the high heating mode, the pump **60** propels atmospheric air into the vane-type device **36** through the compression chamber inlet **52**. The temperature and pressure of the air both increase as the air is compressed in the compression chambers **48**. The pressurized and warmed air then exits the vane-type device **36** through the compression chamber outlet **54** and flows into the combustion chamber **62**. In the combustion chamber **62**, the fuel is mixed with the air and combusted to greatly increase the pressure and temperature of the air. The air then flows through the heat exchanger **32** where it dispenses heat to warm the target space **22**. Next, the valve **64** directs a predetermined amount of the air to the expansion chamber inlet **56** of the vane-type device **36** and the remaining air to the secondary expander **66**. In the vane-type device **36**, the pressurized air is expanded, preferably to or nearly to the atmospheric pressure, before it is discharged out of the flow path **24** and to the atmosphere **30** through the outlet **28**. A secondary heat exchanger (not shown) may be incorporated into the flow path **24** between the expansion chamber outlet **58** and the flow path outlet **28** to scavenge any remaining heat in the working fluid and thereby further increase thermodynamic efficiencies. Ideally, the temperature of the working fluid as it emerges from the outlet **28** is at or only very slightly greater than the ambient air temperature. The air in the secondary expander **66** is also expanded, preferably to or nearly to atmospheric pressure, while powering the generator **68** to produce electricity. After the air is expanded by the secondary expander **66**, it is also directed to the outlet **28** to be discharged to the atmosphere **30**.

[0034] Through reconfiguration, the embodiment of FIG. **1** can also work in a cooling capacity in its standard heating/cooling mode. There are many ways to reconfigure the system. One way to switch the system to the cooling operating mode is to rotate the vane-type device **36** by one hundred and eighty degrees (180°). In another technique, the rotor **42** could be moved in a radially upward direction (i.e., shifted upward) while the stator housing **38** remains stationary. Both of these reconfiguration methods effectively transform the compression chambers **48** into the expansion chambers **50** and vice versa. When operating in the cooling operating mode, the pump **60** first propels the atmospheric air into the expansion chambers **50** of the vane-type device **36** to reduce the pressure and temperature of the air. The combustion chamber **62** is dormant. The cooled air receives heat from the heat exchanger **32** to cool the target space **22**. The air is then re-pressurized in the compression chambers **48** of the vane-type device **36**, preferably to atmospheric pressure, before being dispensed to the atmosphere **30** through the outlet **28**.

[0035] The vane-type device **36** can also work in a closed loop system **70**, as generally shown in FIG. **2**. In the closed loop system **70**, the working fluid may be air or a refrigerant. Like the open-loop system of FIG. **1**, the compression chamber inlet **52** and expansion chamber outlet **58** are generally longitudinally aligned with one another for simultaneously communicating with the same chamber **48**, **50**. A high-pressure side heat exchanger **72** is fluidly connected to the vane-type device **36** through the compression chamber outlet **54** and the expansion chamber inlet **56**. A low-pressure side heat exchanger **74** is fluidly connected to the vane-type device **36** through the expansion chamber outlet **58** and the compression chamber inlet **52**.

[0036] The closed loop system **70** FIG. **2** has two operating modes: a first operating mode and a second operating mode. Either the high pressure side heat exchanger **72** or the low-pressure side heat exchanger **74** may be disposed in a target space to be selectively heated or cooled or outside of the target space in the atmosphere.

[0037] In the first operating mode, the rotor **42** rotates in a first direction, causing the pressure and temperature of the working fluid in the compression chambers **48** to increase as the volume of those compression chambers **48** decreases. That working fluid then flows into the high-pressure side heat exchanger **72** where it dissipates heat to either the target space or the atmosphere. The pressurized and cooled working fluid then flows into the expansion chambers **50** through the expansion chamber inlet **56**. In the expansion chambers **50**, the temperature and the pressure of the working fluid decrease as the volume of the expansion chambers **50** increases. The working fluid leaves the expansion chambers **50** through the expansion chamber outlet **58** and flows to the low-pressure side heat exchanger **74**. In the low-pressure side heat exchanger **74**, the working fluid receives heat from either the target space or the atmosphere before flowing back into the compression chambers **48**.

[0038] Similar to the open loop embodiment of FIG. **1**, the vane-type device **36** of FIG. **2** can be switched to the second operating mode through reconfiguring. Specifically, the vane-type device **36** can be rotated by one hundred and eighty degrees (180°), or the rotor **42** could be moved radially within the stator housing **38**. This reconfiguring effectively reverses the functionality of the high-pressure side heat exchanger **72** and the low-pressure side heat exchanger **74**. In other words, the low-pressure side heat exchanger **74** becomes the high-pressure side heat exchanger **72** and dissipates heat, and the high-pressure side heat exchanger **32**, **72** becomes the low-pressure side heat exchanger **74** and receives heat.

[0039] FIG. **3** shows the vane-type device **36** in a cooling open-loop system. Similar to the embodiment of FIG. **1**, air is used as the working fluid in the embodiment of FIG. **3**. Unlike the embodiment of FIG. **1**, the inlet **26** and the outlet **28** are disposed in the target space **22** for using air from the target space **22** as the working fluid. In the embodiment of FIG. **3**, the compression chamber inlet **52** of the stator housing **38** is generally longitudinally aligned with the expansion chamber outlet **58** of the stator housing **38**. A heat exchanger **32** disposed in the atmosphere **30** is fluidly connected to the vane-type device **36** through the compression chamber outlet **54** and the expansion chamber inlet **56**. In operation, the air in the target space **22** enters the flow path **24** through the inlet **26**, and the blower propels the air into the vane-type device **36** through the compression chamber inlet **52**. The pressure and temperature of the air increase as the volume of the compression chambers **48** decreases. The air leaves the vane-type device **36** through the compression chamber outlet **54** and flows to the heat exchanger **32**. In the heat exchanger **32**, the warmed and pressurized air dispenses heat to the atmosphere **30** before flowing back into the vane-type device **36** through the expansion chamber inlet **56**. In the vane-type device **36**, the pressure and temperature of the air decrease as the volume of the expansion chambers **50** increases. The air entering the vane-type device **36** then pushes the cooled and depressurized air out of the vane-type device **36** through the expansion chamber outlet **58**. The air then exits the flow path **24** through the outlet **28** at a cooler temperature than it was when entering the flow path **24**, thereby cooling the target space **22**.

[0040] FIG. **4** shows the vane-type device **36** in a heating open loop system. Similar to the embodiment of FIG. **3**, the inlet **26** and the outlet **28** are disposed in the target space **22** for using the air in the target space **22** as the working fluid. In the embodiment of FIG. **4**, the expansion chamber inlet **56** of the stator housing **38** is generally longitudinally aligned with the compression chamber outlet **54** of the stator housing **38**, and the compression chamber inlet **52** of the stator housing **38** is generally longitudinally aligned with the expansion chamber outlet **58** of the stator housing **38**. A heat exchanger **32** disposed in the atmosphere **30** is fluidly connected to the expansion chamber outlet **58** and the compression chamber inlet **52**. In operation, the air of the target space **22** enters the flow path **24** through the inlet **26**, and the blower propels the air into the vane-type device **36** through the expansion chamber inlet **56**. The pressure and temperature of the air decrease as the volume of the expansion chambers **50** increases. The air leaves the vane-type device **36** through the expansion chamber outlet **58** and flows to the heat exchanger **32**. In the heat exchanger **32**, the cooled and depressurized air receives heat from the atmosphere **30** before being propelled back into the vane-type device **36** through the compression chamber inlet **52** by another pump **60**. The warmed and still depressurized air entering the vane-type device **36** through the compression chamber inlet **52** also pushes the cooled and depressurized air out of the vane-type device **36** through the expansion chamber outlet **58**. In the vane-type device **36**, the pressure and temperature of the air increase as the volume of the compression chambers **48** decreases. The air entering the vane-type device **36** through the expansion chamber inlet **56** then pushes the warmed and re-pressurized air out of the vane-type device **36** through the compression chamber outlet **54**. The air then exits the flow path **24** through the outlet **28** at a warmer temperature than it was when entering the flow path **24**, thereby warming the target space **22**.

[0041] An open-loop air aspirated hybrid heat pump and heat engine system **20** having a compressor **76** separated from the expander **78** is generally shown in FIG. **5**. Similar to the embodiment of FIG. **1**, atmospheric air is used as the working fluid in the embodiment of FIG. **5**. In the embodiment of FIG. **5**, the heat exchanger **32** is disposed in the target space **22** for transferring heat between the air in the flow path **24** and the target space **22**, and the inlet **26** and the outlet **28** are disposed outside of the target space **22** in the atmosphere **30**. A compressor **76** is disposed in the flow path **24** between the inlet **26** and the heat exchanger **32** for compressing and delivering the air from the inlet **26** to the heat exchanger **32**. An expander **78** is disposed in the flow path **24** between the heat exchanger **32** and the outlet **28** for expanding (i.e. depressurizing) and delivering the air from the heat exchanger **32** to the outlet **28**. In the exemplary embodiment, the compressor **76** and expander **78** are both vane-type pumps having a cylindrically shaped stator **38** and a rotor **42** rotatably disposed within the stator **38**. A plurality of spring-loaded vanes **46** project outwardly from the rotor **42** to slidably engage the inner wall **44** of the stator **38**. However, it should be appreciated that the compressor **76** and the expander **78** could be any type of pumps.

[0042] An energy receiving device is mechanically connected to the expander **78** for harnessing potential energy from the air in the flow path **24** as will be discussed in further detail below. In the exemplary embodiment, the energy receiving device is a generator **68** for generating electricity. The electricity can then be used immediately, stored in batteries or inserted into the power grid. Alternatively or additionally, the energy receiving device could be a mechanical connection between the expander **78** and the compressor **76** for powering the compressor **76** with the energy reclaimed from the air in the flow path **24**. The energy receiving device could also be any other device for harnessing the energy produced by the expander **78**.

[0043] A controller **82** is in communication with the compressor **76** and the expander **78** for controlling the hybrid heat pump and heat engine system **20**. The controller **82** manipulates or switches the system **20** between different operating modes: a standard heating/cooling mode (in which the target space **22** can be either heated or cooled), and a high heating mode (in which the target space **22** is heated). The operating mode may be selected by a person, or the controller **82** can be coupled to a thermostat for automatically keeping the target space **22** at a desired temperature.

[0044] In reference to FIG. **5**, the working fluid (e.g., air) travels through the flow path **24** in a clockwise direction. In the standard cooling operating mode, the controller **82** directs the compressor **76** to operate at a low speed and the expander **78** to operate at a higher speed. What follows is that the compressor **76** functions similarly to a valve separating the air downstream of the compressor **76** from the air at the inlet **26** of the flow path **24**. The expander **78** then pulls the air along the flow path **24** by reducing the pressure of the air from the compressor **76** to the expander **78**. Persons skilled in the art will appreciate that the temperature of the air leaving the compressor **76** will decrease as the pressure decreases. In other words, both the pressure and temperature of the air on the downstream side of the compressor **76** are reduced when compared to the pressure and temperature of the air at the inlet. The depressurized and cooled air then flows through the heat exchanger **32**, which transfers heat from the target space **22** to the air in the flow path **24** to cool the target space **22**. After leaving the heat exchanger **32**, the expander **78** propels the air out of the flow path **24** through the outlet **28**. Alternatively, the direction of the air may be reversed to flow in a counter-clockwise direction if this makes better use of the devices chosen with the final engineering targets in mind. In the cooling operating mode, the energy receiving device may be mechanically connected to the compressor **76** for harnessing the potential pressure energy from the air flowing through the compressor **76**.

[0045] In the standard heating mode, the controller **82** directs the compressor **76** to compress the air from the inlet to increase the pressure and the temperature of the air, as will be understood by those skilled in the art. The pressurized and warmed air then flows through the flow path **24** to the heat exchanger **32**. The heat exchanger **32** dispenses heat to the target space **22** to warm the target space **22**. Although the air in the flow path **24** is cooled by the heat exchanger **32**, the air remains pressurized when compared to the air entering the flow path **24**. This difference in pressure represents potential energy, which can be harnessed. The generator **68**, which is coupled to the expander **78**, harnesses this potential energy while the expander **78** expands the pressurized air to reduce the pressure of the air. Preferably, the air is expanded back to the same pressure at which it entered the flow path **24**. Following the expansion, the air is discharged from the flow path **24** through the outlet **28**.

[0046] In the high heating mode, the compressor **76** receives air aspirated from the inlet **26** and then compresses the air to increase its pressure and also its temperature (in compliance with relevant thermodynamic gas laws). The pressurized and high temperature air then flows through the flow path **24** to the combustion chamber **62**, which mixes a suitable fuel with the air and then combusts the mixture. The combustion of the fuel and air mixture further increases both the pressure and the temperature of the air in the flow path **24**. The pressurized and heated air then flows through the heat exchanger **32** and dispenses heat to the target space **22**. Air leaving the heat exchanger **32** in the high heating mode remains substantially highly pressurized relative to the ambient air pressure, and therefore represents a valuable amount of potential energy. The generator **68** maybe of any suitable type that is effective to convert this potential energy into another form, such as electricity and/or mechanical energy. This potential energy may be harnessed while the expander **78** expands the air to reduce the pressure of the air, or accumulated for conversion at a later time. In other words, any residual pressure energy put into the air through the initial compression and combustion processed is subsequently reclaimed by the generator **68**. Once the potential energy has been reclaimed, the low pressure air is then discharged from the flow path **24** through the outlet **28** back into the environment **30**.

[0047] Obviously, many modifications and variations of the present invention are possible in light of the above teachings and may be practiced otherwise than as specifically described while within the scope of the appended claims. These antecedent recitations should be interpreted to cover any combination in which the inventive novelty exercises its utility. The use of the word "said" in the apparatus claims refers to an antecedent that is a positive recitation meant to be included in the coverage of the claims whereas the word "the" precedes a word not meant to be included in the coverage of the claims. In addition, the reference numerals in the claims are merely for convenience and are not to be read in any way as limiting.

What is claimed is:

1. A high-efficiency air moving system for circulating ambient air in a target space across a heat exchanger, said system comprising:
- a confined flow path for routing ambient air as a working fluid from an inlet to an outlet, said inlet disposed to receive ambient air from the target space as the working fluid and said outlet disposed for expelling the air out of said flow path and back into the ambient air in the target space,
- a first turbine disposed in said flow path adjacent said inlet, said first turbine configured to control substantially all of the movement of air entering said flow path through said inlet,
- a second turbine disposed in said flow path adjacent said outlet, said second turbine configured to control substantially all of the movement of air exiting said flow path through said outlet,
- a heat exchanger disposed in said flow path between said first and second turbine, said heat exchanger configured to move heat into or out of the air in said flow path and thereby heat or cool the air in the target space when the air is subsequently discharged from said outlet, and wherein movement of heat into or out of the air in said flow path causes a corresponding differentiated pressure of the air between said first and second turbines relative to the ambient air, and
- at least one of said first turbine and said second turbine being configured to harvest work from the differentiated pressure of the air between said first and second turbines.

2. The system as set forth in claim **1**, further including an electric generator operatively coupled to one of said first and second turbines for generating electricity from the harvested work.

3. The system as set forth in claim **1**, wherein at least one of said first turbine and said second turbine comprises a positive displacement vane pump.

4. The system as set forth in claim **1**, further including a transmission in communication with said first turbine and said second turbine, said transmission configured to transfer work harvested from one of said first and second turbines directly to the other of said first and second turbines.

5. The system as set forth in claim **1**, wherein said heat exchanger moves heat out of the air in said flow path, and said first turbine harvests work from the differentiated pressure of the air between said first and second turbines.

6. The system as set forth in claim **1**, wherein said heat exchanger moves heat into the air in said flow path, and said second turbine harvests work from the differentiated pressure of the air between said first and second turbines.

7. The system as set forth in claim **1**, further including a combustion chamber in said flow path between said first turbine and said heat exchanger.

8. A high-efficiency air moving system for circulating ambient air in a target space across a heat exchanger, said system comprising:
- a confined flow path for routing ambient air as a working fluid from an inlet to an outlet, said inlet disposed to

receive ambient air from the target space as the working fluid and said outlet disposed for expelling the air out of said flow path and back into the ambient air in the target space,

a first pump disposed in said flow path adjacent said inlet, said first pump configured to control substantially all of the movement of air entering said flow path through said inlet,

a second pump disposed in said flow path adjacent said outlet, said second pump configured to control substantially all of the movement of air exiting said flow path through said outlet,

a heat exchanger disposed in said flow path between said first and second pump, said heat exchanger configured to move heat into or out of the air in said flow path and thereby heat or cool the air in the target space when the air is subsequently discharged from said outlet, and wherein movement of heat into or out of the air in said flow path causes a corresponding differentiated pressure of the air between said first and second pumps relative to the ambient air, and

at least one of said first pump and said second pump being configured to harvest work from the differentiated pressure of the air between said first and second pumps.

9. The system as set forth in claim **8**, further including an electric generator operatively coupled to one of said first and second pumps for generating electricity from the harvested work.

10. The system as set forth in claim **8**, wherein at least one of said first pump and said second pump comprises a positive displacement vane pump.

11. The system as set forth in claim **8**, further including a transmission in communication with said first pump and said second pump, said transmission configured to transfer work harvested from one of said first and second pumps directly to the other of said first and second pumps.

12. The system as set forth in claim **8**, wherein said heat exchanger moves heat out of the air in said flow path, and said first pump harvests work from the differentiated pressure of the air between said first and second pumps.

13. The system as set forth in claim **8**, wherein said heat exchanger moves heat into the air in said flow path, and said second pump harvests work from the differentiated pressure of the air between said first and second pumps.

14. The system as set forth in claim **8**, further including a combustion chamber in said flow path between said first pump and said heat exchanger.

15. A high-efficiency air moving system for circulating ambient air in a target space across a heat exchanger, said system comprising:

a confined flow path for routing ambient air as a working fluid from an inlet to an outlet, said inlet disposed to receive ambient air from the target space as the working fluid and said outlet disposed for expelling the air out of said flow path and back into the ambient air in the target space,

a first positive displacement vane pump disposed in said flow path adjacent said inlet, said first positive displacement vane pump configured to control substantially all of the movement of air entering said flow path through said inlet,

a second positive displacement vane pump disposed in said flow path adjacent said outlet, said second positive displacement vane pump configured to control substantially all of the movement of air exiting said flow path through said outlet,

a heat exchanger disposed in said flow path between said first and second positive displacement vane pumps, said heat exchanger configured to move heat into or out of the air in said flow path and thereby heat or cool the air in the target space when the air is subsequently discharged from said outlet, and wherein movement of heat into or out of the air in said flow path causes a corresponding differentiated pressure of the air between said first and second positive displacement vane pumps relative to the ambient air, and

at least one of said first positive displacement vane pump and said second positive displacement vane pump being configured to harvest work from the differentiated pressure of the air between said first and second positive displacement vane pumps.

16. The system as set forth in claim **15**, further including an electric generator operatively coupled to one of said first and second positive displacement vane pumps for generating electricity from the harvested work.

17. The system as set forth in claim **15**, further including a transmission in communication with said first positive displacement vane pump and said second positive displacement vane pump, said transmission configured to transfer work harvested from one of said first and second positive displacement vane pumps directly to the other of said first and second positive displacement vane pumps.

18. The system as set forth in claim **15**, wherein said heat exchanger moves heat out of the air in said flow path, and said first positive displacement vane pump harvests work from the differentiated pressure of the air between said first and second positive displacement vane pumps.

19. The system as set forth in claim **15**, wherein said heat exchanger moves heat into the air in said flow path, and said second positive displacement vane pump harvests work from the differentiated pressure of the air between said first and second positive displacement vane pumps.

20. The system as set forth in claim **15**, further including a combustion chamber in said flow path between said first positive displacement vane pump and said heat exchanger.

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