US 20090139254A1

(19) **United States**

(12) **Patent Application Publication**

Landry

(10) **Pub. No.: US 2009/0139254 A1**

(43) **Pub. Date: Jun. 4, 2009**

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(54) **THERMODYNAMIC CLOSED LOOP DESICCANT ROTOR SYSTEM AND PROCESS**

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(21) Appl. No.: **12/315,569**

(22) Filed: **Dec. 3, 2008**

Related U.S. Application Data

(60) Provisional application No. 61/005,011, filed on Dec. 3, 2007.

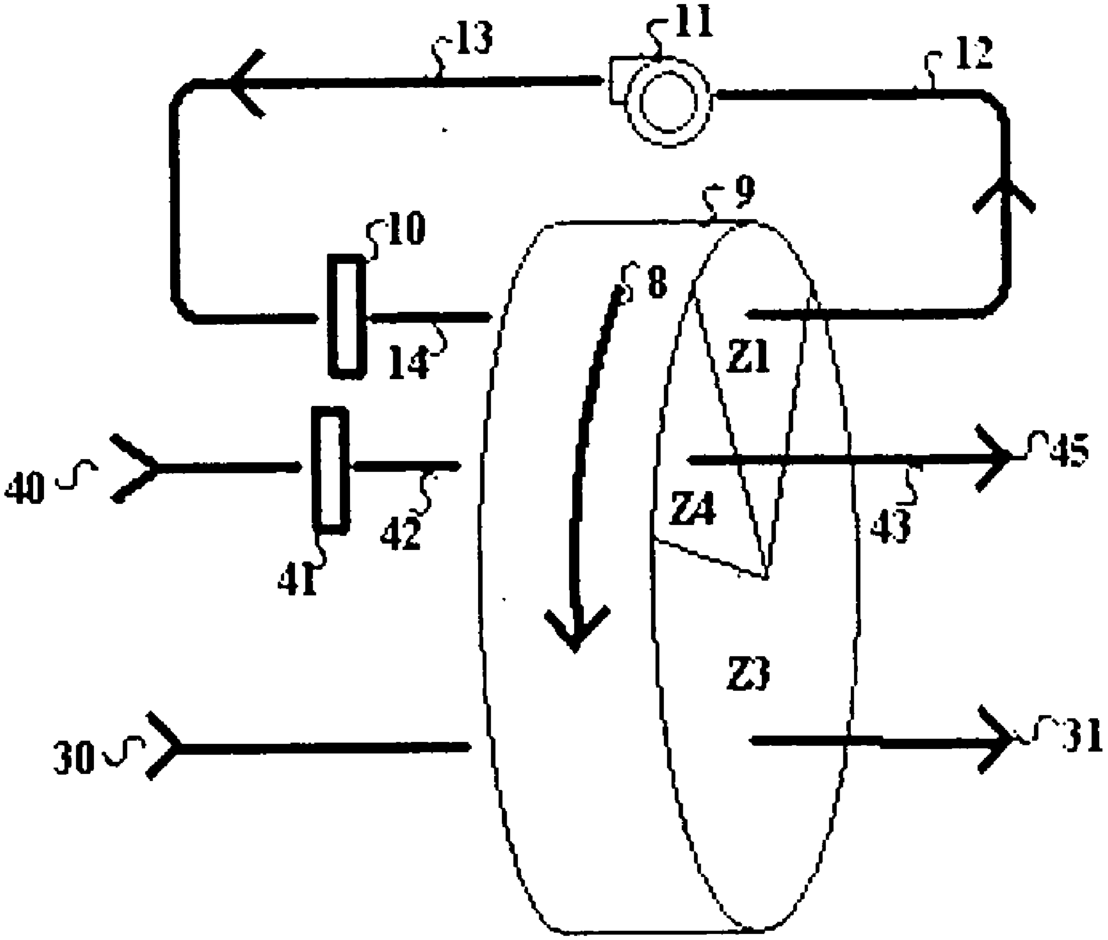
Publication Classification

(51) **Int. Cl.**
F25D 17/06 (2006.01)

(52) **U.S. Cl.** **62/271**; 62/94

(57) **ABSTRACT**

A thermodynamic closed loop desiccant rotor system and process utilizes at least one closed recirculation loop that provides interchangeable energy directly to the desiccant material and various rotor isolated zoning configurations in combination with various arrangements of energy exchange devices and refrigeration components to maximize the interchangeable and recovered energy capability and capacity through both closed thermodynamic cycles and open cycle processes for significantly improved efficiency and energy conservation. The present desiccant rotor system may be utilized in an air conditioning system for dehumidification, humidification, moisture removal, and capture of moisture, and in other applications to remove unwanted gases.



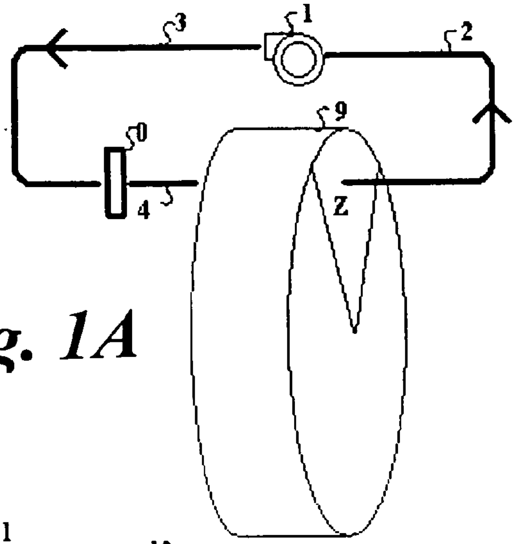


Fig. 1A

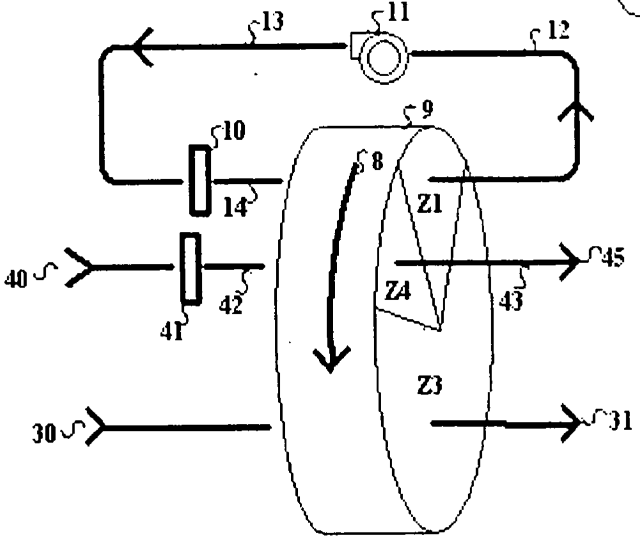


Fig. 1B

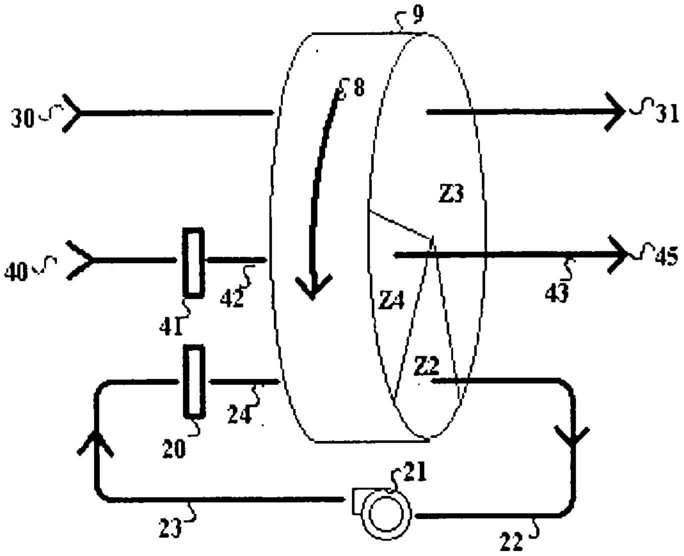
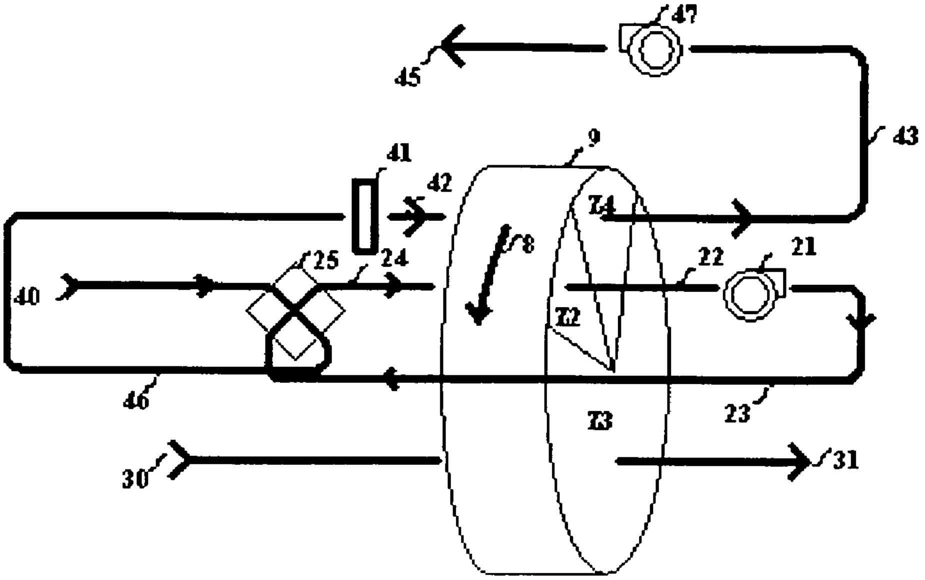


Fig. 1C


47
45
43
9
41
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Z4
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Z2
46
23
Z3
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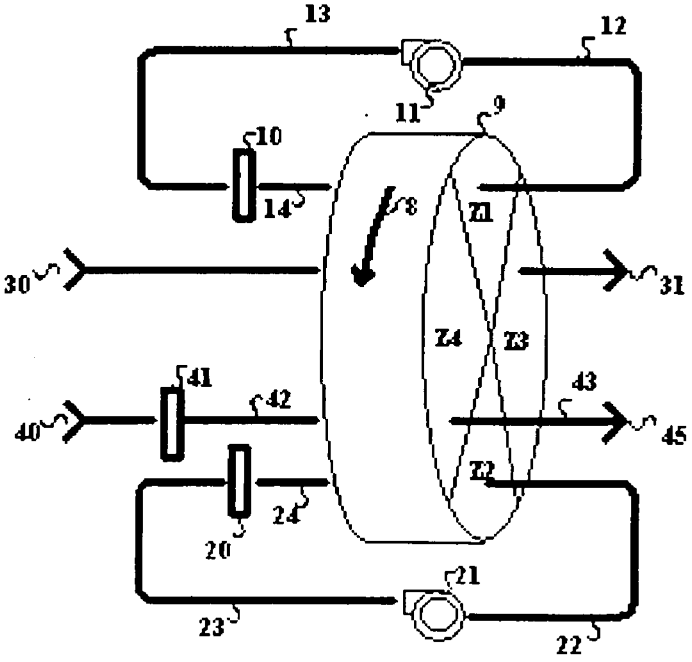
31

Fig. 2A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11
9
10
14
8
Z1
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31
Z4
Z3
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Z2
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23
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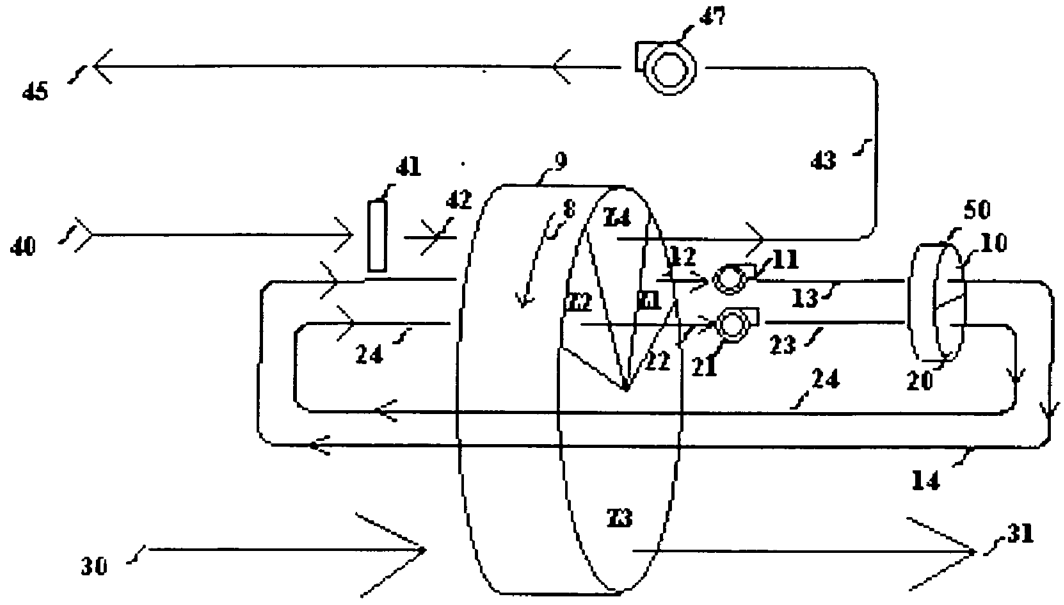
Fig. 2B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Z4
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Z2
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20
14
Z3
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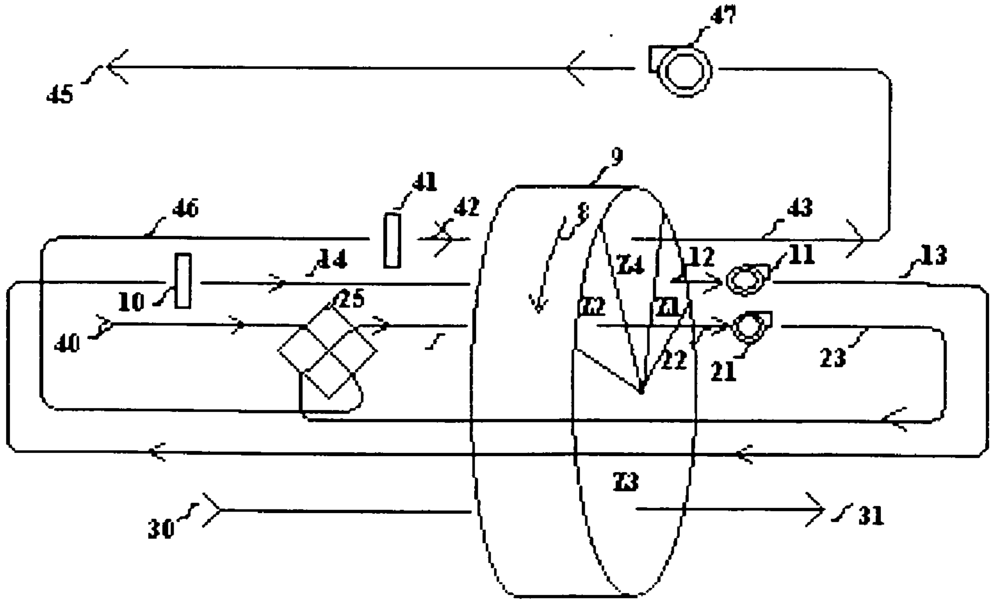
31

Fig. 3A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23
Z3
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Fig. 3B

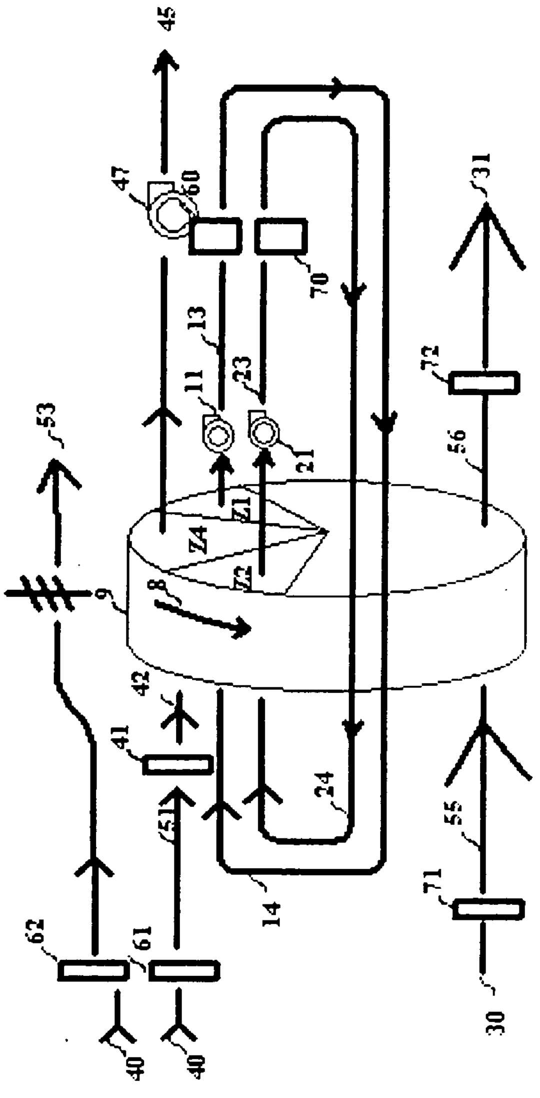


Fig. 4A

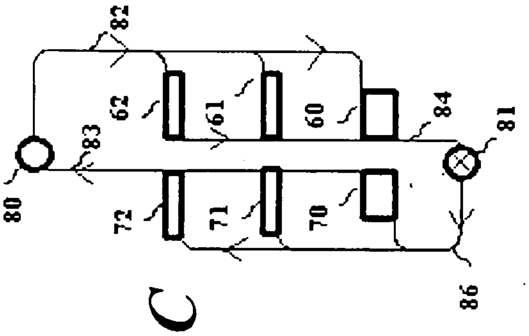


Fig. 4C

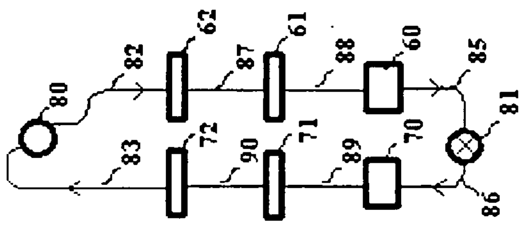
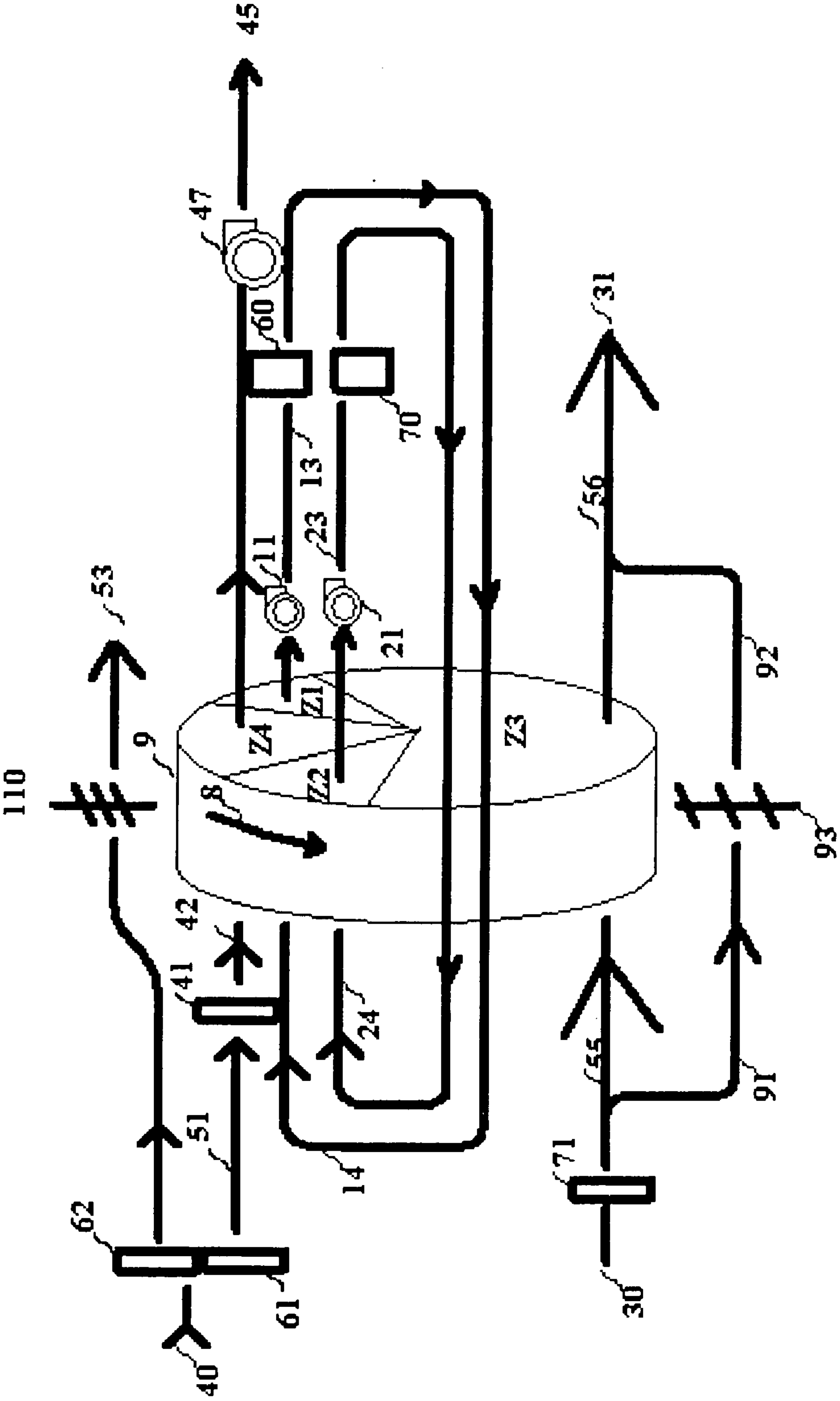


Fig. 4B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110
9
8
Z4
Z1
Z2
Z3
93
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41
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62
61
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91
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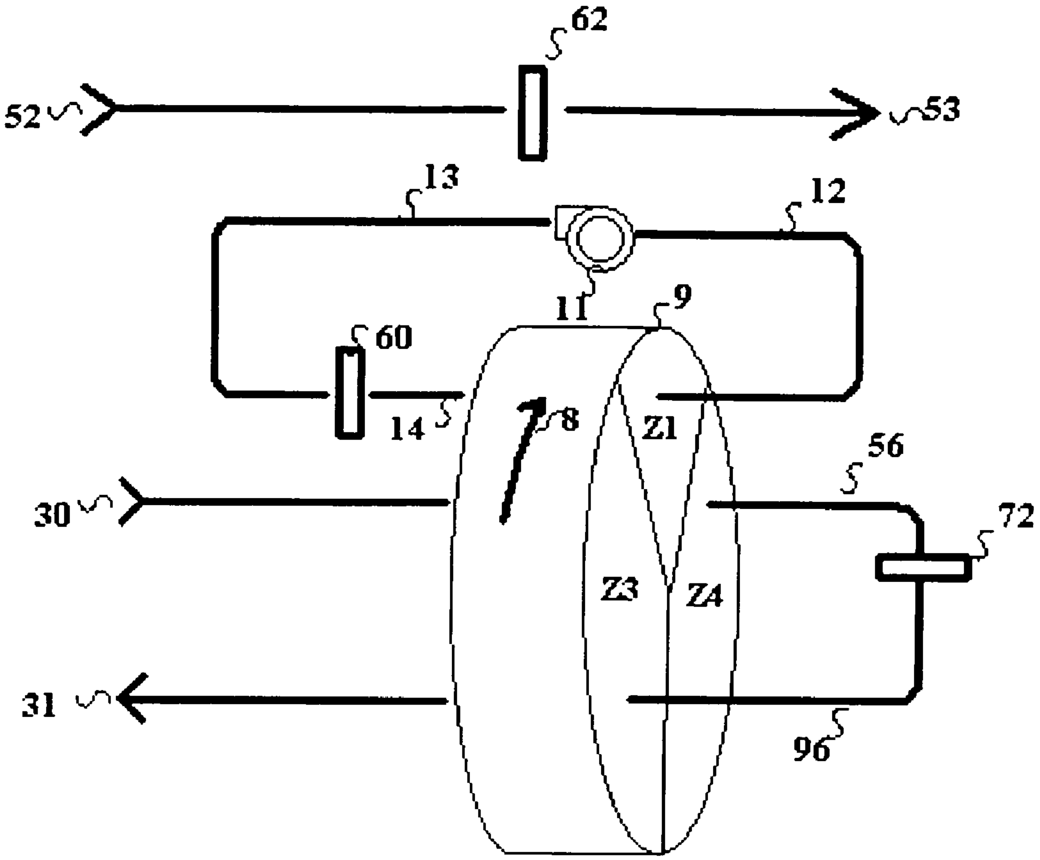
Fig. 5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Z1
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Z3
Z4
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96

Fig. 6A

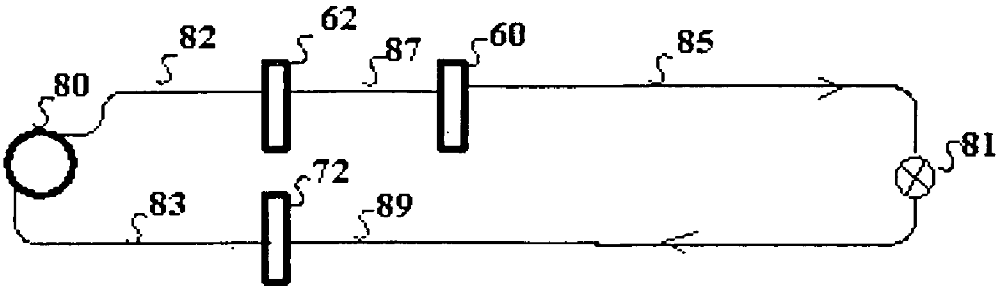
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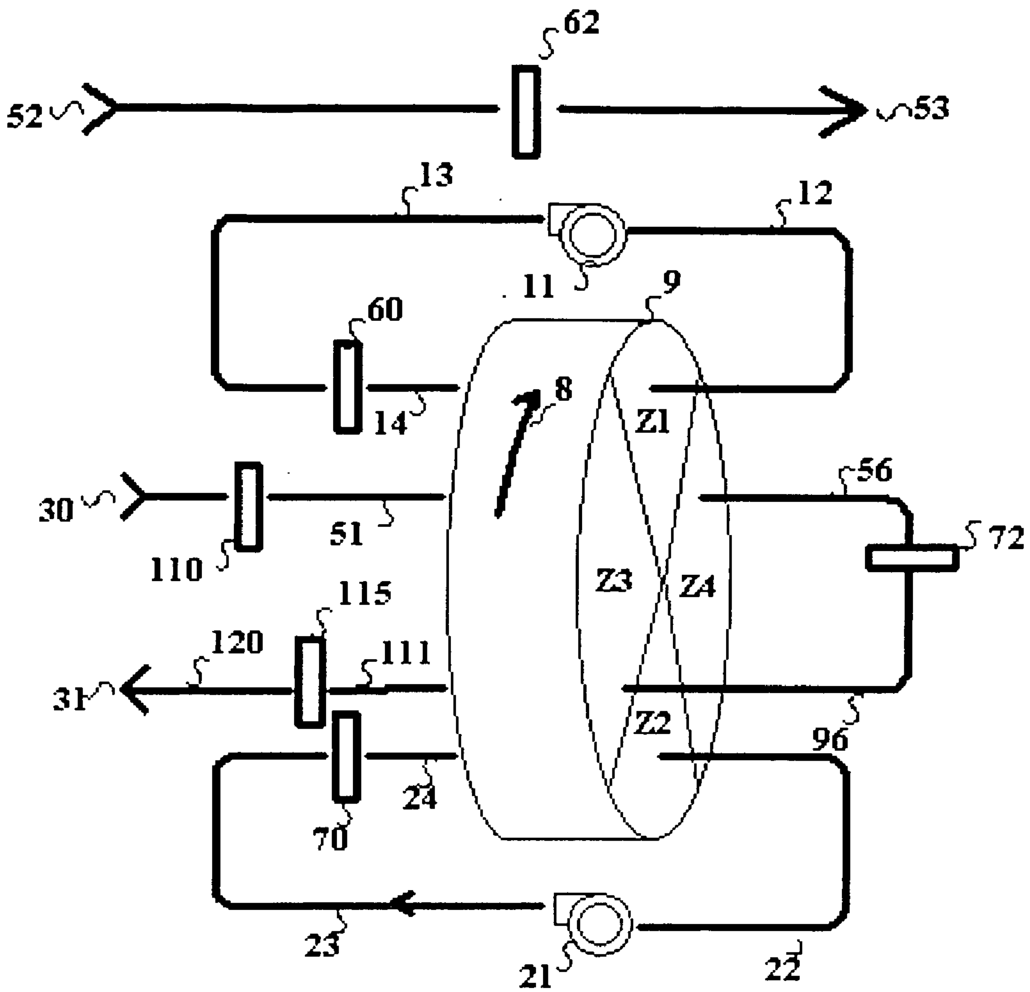
Fig. 6B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9
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14
Z1
56
30
72
51
110
Z3
Z4
115
120
111
31
Z2
96
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Fig. 7A

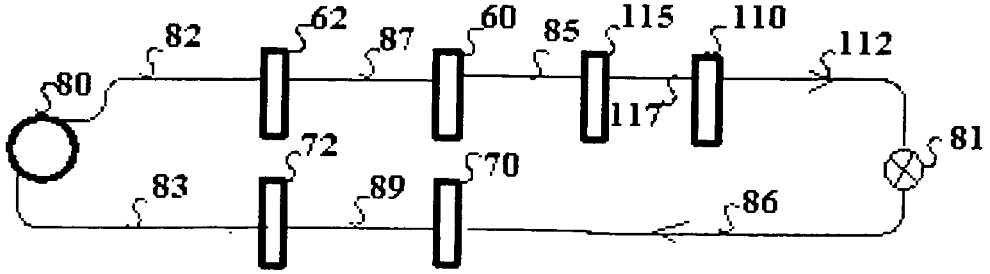
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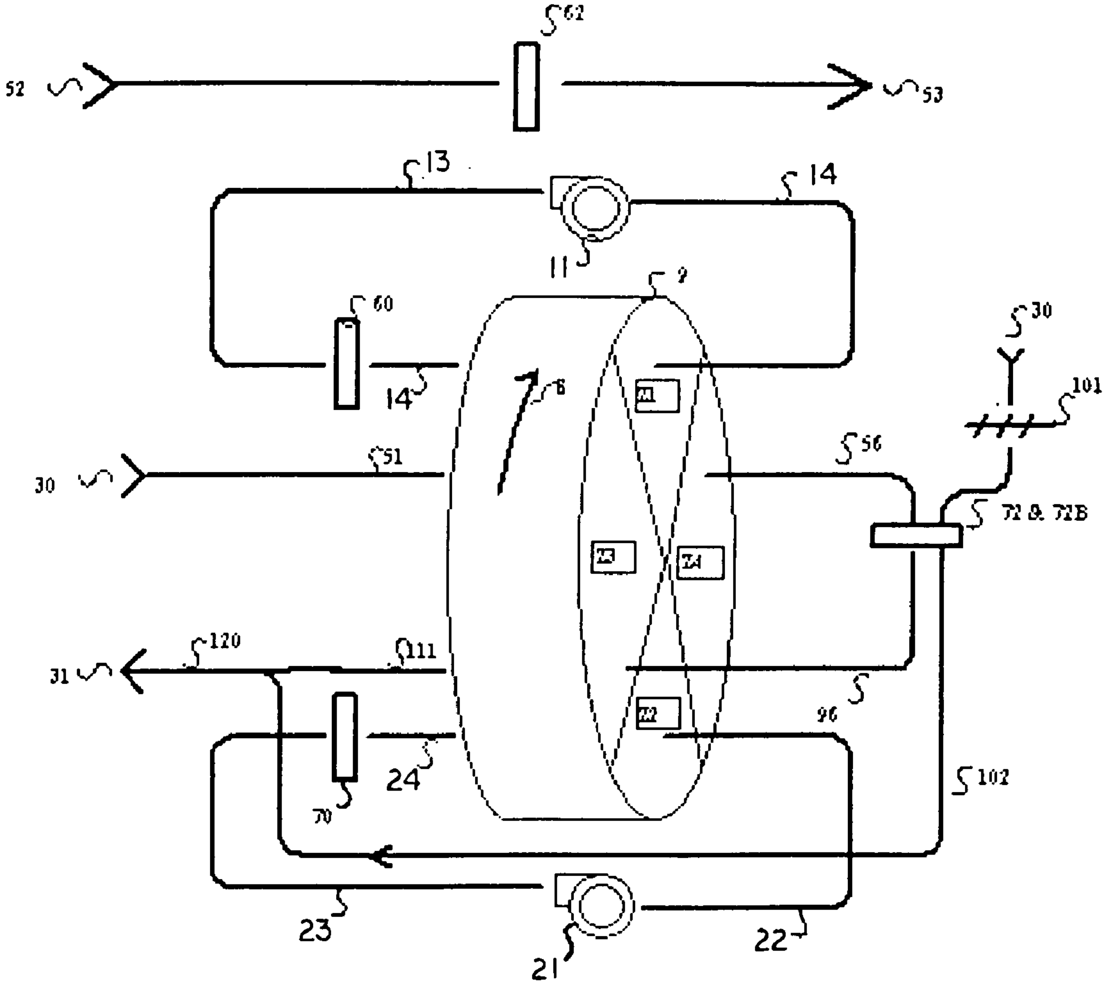
Fig. 7B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13
14
11
9
60
14
8
Z1
30
101
51
56
30
72 & 72B
Z3
Z4
120
111
31
Z2
96
70
24
102
23
22
21

Fig. 8

THERMODYNAMIC CLOSED LOOP DESICCANT ROTOR SYSTEM AND PROCESS

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims priority of U.S. Provisional Application Ser. No. 61/005,011, filed Dec. 3, 2007.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] This invention relates generally to desiccant rotor assisted air conditioning systems and dehumidification processes, and more particularly to a thermodynamic closed loop desiccant rotor system and process which utilizes at least one closed recirculation loop that provides interchangeable energy directly to the desiccant material, and various alternate rotor isolated zoning configurations in combination with various arrangements of energy exchange devices and refrigeration components to maximize the interchangeable and recovered energy capability and capacity through both closed thermodynamic cycles and open cycle processes for significantly improved efficiency and energy conservation.

[0004] 2. Background Art

[0005] Desiccant assisted air conditioning systems are known in the art. Desiccant rotor technology provides effective and efficient dehumidification of air. In most desiccant rotor systems, ionic desiccant materials are adhered or cooked in situ onto a rotor substrate and the rotor rotates between at least two air streams to flow through two separate zones to provide dehumidification or humidification by alternating the energy in a gas phase change process. In one of the zones, the air delivered to the interior of a space to be conditioned crosses the desiccant material, which attracts and holds moisture in a wicking action to adsorb unwanted gases. As the desiccant wheel rotates and enters the second zone, the moist desiccant material is subjected to a regeneration air stream where vapor content, which is then vented away. It is a common practice to condition the air stream prior it entering the regeneration zone of the rotor. The added regeneration energy allows the air to react with the desiccant material in a thermodynamic chemical equilibrium process and reaction rate adequate to condition the desiccant material prior to rotating into the process air stream.

[0006] The useful energy and/or reaction rate between the air and the desiccant material is directionally proportional to the conditioning of the desiccant material. Typically, a great part of the energy added to condition the air is wasted and results in high energy consumption.

[0007] Conventional desiccant rotor technology typically incorporates a rotating desiccant wheel that rotates between two air streams to provide dehumidification or humidification by alternating the energy in a gas phase change process. In such systems, the process air delivered to the interior of a space to be conditioned crosses the desiccant material, which attracts and holds moisture. As the desiccant wheel rotates, the moist desiccant material enters the regeneration air stream where it is heated to release moisture, which is then vented away. Because humidity is a function of vapor pressure, desiccant materials have the ability to remove or add moisture adiabatically; a reversible thermodynamic process in which the energy exchanges result in substantially constant enthalpy equilibrium. The total desiccant open cycle is somewhat similar to a refrigerant vapor-compression cycle. In a desiccant and air system the heated regeneration air adds energy to the moistened desiccant in a de-sorption process and releases moisture in the regenerating crossing air stream in an adiabatic cooling process. When the desiccant rotates to the process air stream the pre-conditioned desiccant enables the sorption of water and dehumidifies the crossing process air and adiabatic re-heat is released in the air stream. This completes the desiccant vapor-compression open cycle.

[0008] Several other practices can be utilized to improve the regeneration of desiccant on the rotor and or diminish the energy usage. Refrigeration can be used to cool the air to a dew point and remove any elevated grain level and excess of humidity in the crossing air. It also can re-use the usually rejected condenser refrigerant energy to re-heat the air prior to entering the regeneration air to the rotor.

[0009] Heat recovery apparatus are also often used. They recover re-usable sensible heat from the regeneration exhaust air and transfer this heat to the regeneration intake air stream.

[0010] Desiccant applications are effective in separating the total air cooling process into two separate processes; latent and sensible energy. Although desiccant technology may sometimes benefit from its adiabatic desiccant re-heating effect provided in the process delivery (supply) air, quite often re-cooling of the process air is needed to provide adequate delivery (supply) air.

[0011] In the existing conventional rotor technology it is a common practice to regenerate the desiccant material in an open type process instead of a closed loop process. In the crossing process air stream, an open cycle is needed since the process involves conditioning the crossing air and separating unwanted gases. In a regeneration process, the useful and effective energy involves preparation of the desiccant prior to rotating it into the process air. In typical conventional application, a crossing agent such as outdoor air is utilized to carry the unwanted gases over to an exhaust and simultaneously regenerate the desiccant material and content. Most conventional regeneration processes typically utilize an open cycle system.

[0012] The heating of the regeneration air stream utilizing part of the surroundings of the isolated desiccant material as a carrying agent is required in a open cycle system and process to remove the unwanted vapors.

[0013] In the refrigerant compression closed cycle of the conventional air conditioning system, a compressor compresses refrigerant gas to increase its pressure and temperature in an isentropic adiabatic process. The refrigerant is then passed through a condenser coil where the superheated compressed refrigerant dissipates its heat to the crossing air stream condensing the refrigerant into a high-pressure liquid, which then flows through a metering device or expansion valve that restricts the high-pressure liquid and creates a reverse refrigerant adiabatic effect, after which, the refrigerant is discharged or suctioned to an evaporator coil at lower refrigerant temperature and pressure conditions, which enable the evaporator coil to absorb heat from the crossing air that is forced through the coil by the evaporator fan. The air exiting the evaporator coil is discharged as cool air and the refrigerant absorption process changes the refrigerant from liquid-gas to gas, which is then suctioned back to the compressor to complete the closed cycle.

SUMMARY OF THE INVENTION

[0014] The present invention is distinguished over the prior art in general by a thermodynamic closed loop desiccant rotor system and process which utilizes at least one closed recirculation loop that provides interchangeable energy directly to the desiccant material and utilized in various alternate rotor isolated zoning configurations, in combination with various arrangements of energy exchange devices and refrigeration components to maximize the interchangeable and recovered energy capability and capacity through both closed thermodynamic cycles and open cycle processes for significantly improved efficiency and energy conservation.

[0015] The present desiccant rotor system may be utilized in an air conditioning system for dehumidification, humidification, moisture removal, and capture of moisture, and it may also be utilized to remove unwanted gases such as carbon dioxide, carbon monoxide, hydrogen, and nitrogen, in the manner of a gas separator, gas accumulator, gas filtering apparatus, or water system accumulator.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] In some of the drawing figures of the present invention, described in detail hereinafter, the heavier lines represent the air flow paths and the thinner lines represent the flow path of refrigerant.

[0017] FIG. **1**A is a diagrammatic view illustrating the basic components of the desiccant rotor system showing the airflow path for routing the air in a continuous closed loop through a single zone in a thermodynamic mode that allows the system to directly condition the desiccant and moisture content.

[0018] FIG. **1**B is a diagrammatic view illustrating an arrangement of the desiccant rotor system components and airflow paths for routing the air in the continuous heating closed loop zone, a regeneration air zone, and a process deliver air zone in a thermodynamic heating mode.

[0019] FIG. **1**C is a diagrammatic view illustrating an arrangement of the desiccant rotor system components and airflow paths for routing the air in the continuous cooling closed loop zone, regeneration air zone, and process deliver air zone in a thermodynamic cooling mode.

[0020] FIG. **2**A is a diagrammatic view illustrating an arrangement of the desiccant rotor system components including a sensible heat energy recovery device or heat exchanger and airflow paths for interchanging sensible energy from a single zone cooling closed thermodynamic loop to an open regeneration air stream.

[0021] FIG. **2**B is a diagrammatic view illustrating an arrangement of the desiccant rotor system components and airflow paths and process utilizing both heating and cooling closed thermodynamic loops simultaneously.

[0022] FIG. **3**A is a diagrammatic view illustrating an arrangement of the desiccant rotor system components including a sensible heat energy recovery device in the form of a second desiccant rotor and airflow paths for interchanging and recovering energy from dual zone closed thermodynamic loops.

[0023] FIG. **3**B is a diagrammatic view of the arrangement similar to FIG. **3**A, illustrating the airflow paths for interchanging sensible energy from the cooling closed loop to an open regeneration air stream and also directly conditioning the desiccant in the heating closed loop.

[0024] FIG. **4**A is a diagrammatic view illustrating an arrangement of the desiccant rotor system similar to FIGS. **3**A and **2**B utilizing dual closed loops in combination with a refrigeration system for added energy transfer capability.

[0025] FIGS. **4**B and **4**C are diagrammatic views of the piping and refrigeration coils of FIG. **4**A illustrating a series arrangement of the refrigeration coils, and a parallel arrangement of the refrigeration coils, respectively.

[0026] FIG. **5** is a diagrammatic view illustrating a modification of FIG. **4**A wherein the process air stream has a bypass air path that bypasses the process air desiccant zone of the desiccant rotor.

[0027] FIG. **6**A is a diagrammatic view illustrating an arrangement of the desiccant rotor system utilizing a closed loop similar to FIG. **1**B in combination with a refrigeration system, wherein the process intake air crosses the desiccant rotor twice, first through a regeneration process, after crossing a dehumidifying refrigerant cooling coil, and re-crossing the rotor a second time as process air to be discharged as supply air.

[0028] FIG. **6**B is a diagrammatic view of the piping and refrigeration coils of FIG. **6**A illustrating a series refrigeration coil arrangement.

[0029] FIG. **7**A is a diagrammatic view illustrating an arrangement of the desiccant rotor system similar to FIG. **6**A utilizing dual closed loops as described above and in FIGS. **1**B, **1**C and **2**B in combination with a refrigeration system, and wherein the process intake air crosses the desiccant rotor at two different desiccant zones.

[0030] FIG. **7**B is a diagrammatic view of the piping and refrigeration coils of FIG. **7**A illustrating a series refrigeration coil arrangement.

[0031] FIG. **8** is a diagrammatic view illustrating a modification of FIG. **7**A wherein the process air stream has a bypass air path that bypasses the process air desiccant zone of the desiccant rotor.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0032] Detailed descriptions of several preferred embodiments are provided herein having arrangements of components and desiccant rotors with zoning features for carrying out various processes. It is to be understood, however, that the present invention may be embodied in various forms and combinations. Therefore, specific details disclosed herein are not to be interpreted as limiting, but rather as a basis for the claims and as a representative basis for teaching one skilled in the art to employ the present invention in virtually any appropriately detailed system, process, structure or manner.

[0033] As used herein, the term "air conditioning" is a general term meaning a system for controlling the temperature and humidity of air and other gases and includes dehumidification, humidification, and moisture release. Air conditioning systems for treating or conditioning and gases may include, for example, such systems as cooling systems, heating systems, gas separators, gas concentrators, and drinking water accumulators. As used herein, the term "conditioned air" is a general term and includes dehumidified air, humidified air, and cool or warm air, or a combination thereof. The term "process air" means any air that is to be processed by the present system, and may be pre-conditioned by various methods. The term "regeneration air" means any air that is used to regenerate the desiccant material. The term "delivery or supply air" means the air that is supplied to a spaced to be provided with conditioned air. The term "return air" means the air either returning from the conditioned space and may include newly introduced air.

[0034] The term “energy exchange device” means any device that enables the exchange of energy between two air streams in an air heating or cooling process. Examples of suitable “energy exchange devices” include: a refrigerant condenser, evaporator, heat pipes, water or radiator type coils, gas/oil fired device, heat exchangers, electric heater, thermoelectric heater, sensible energy exchanger, plated type heat exchanger, a second rotor, or solar energy device. The term “sensible heat exchanger” means any type of heat exchanger such as a plate type, rotor type, heat pipe any device which enables the exchange of energy between two airs streams, favoring sensible energy. The term “desiccant rotor” means any type of rotor device having the capability of interchanging either latent and/or sensible energy and/or moisture. The term “desiccant” means a drying substance or agent and may include materials such as silicas, aluminas, titanium, lithium chloride, zeolites, polymers, clay, molecular sieves, hydrophilic substances and sorbents. The term “compressor” is a device utilized in a refrigeration process to compress the refrigerant. This device can be modulating, capacity controlled or any combination of several compressors. The term “evaporator” is a refrigerant coil device in which the refrigerant adsorbs energy from a crossing air stream. The term “condenser” means a refrigerant coil device that dissipates its refrigerant energy in its crossing air stream.

[0035] It should be understood that in some of the arrangements described and shown hereinafter, the “energy exchange devices” are assigned different numerals of reference when referring to a specific type of heating or cooling energy exchange device, such as, for example, a refrigerant condenser coil or evaporator coil. In the following discussion, for purposes of example only, the invention will be described in various preferred forms, as an air conditioning system for dehumidification, humidification, moisture removal, and capture of moisture, however, it should be understood that the present invention is not limited to performing only that function. The present desiccant rotor system and process may also be utilized to remove unwanted gases such as carbon dioxide, carbon monoxide, hydrogen, and nitrogen, in the manner of a gas separator, gas accumulator, gas filtering apparatus, or water system accumulator.

[0036] Referring now to FIG. **1**A the basic components of the desiccant rotor system are shown schematically and the airflow paths shown are for routing the air in a continuous closed loop single zone thermodynamic process that allows the system to directly condition the desiccant and moisture content. All of the other drawing figures and processes described hereinafter are derived from the fundamental components and process described in FIG. **1**A but in various different combinations and applications.

[0037] In FIG. **1**A, the basic components shown are a desiccant rotor wheel **9** having a single isolated zone Z of desiccant material, an energy exchange device **0** such as a heat exchanger or other means that enables the exchange of energy between two air streams, and a zone circulating fan **1**. The exhaust outlet of the zone circulating fan **1** is connected in fluid communication with the entering side of the energy exchange device **0** which is connected in fluid communication with the isolated zone Z of the desiccant rotor **9** which is connected in fluid communication with the intake of the zone circulating fan.

Method of Operation

[0038] The zone circulating fan **1** discharges air in an airflow path **3** that passes across the energy exchange device **0** where it is heated or cooled and exchanges its energy to achieve a higher or lower temperature and changed vapor condition. The conditioned air stream **4** leaving the energy exchange device passes across the isolated zone Z of the desiccant rotor **9** to directly condition the desiccant and moisture content. The desiccant material and content reacts to achieve an equilibrium state with the crossing air stream and the crossing air stream exits the isolated zone as air stream **2** having different lower or higher temperature and vapor conditions as compared to the entering air. The air stream **2** leaving the isolated zone of the rotor returns to the intake of the zone circulating fan **1** in a continuous closed loop thermodynamic heating or cooling process. The continuous closed loop thermodynamic process is a continuous recirculation loop that provides a constant source of added or removed heat energy which affects the desiccant temperature and vapor conditions.

[0039] Optionally, an amount of air can be introduced and/or exhausted anywhere in the continuous closed loop air steam, from any other zones or air paths crossing any part of the rotor or outside of the rotor. It should be understood that the rotor may have several isolated zones of desiccant material in fluid communication with several air streams in closed loop and/or open loop configurations. It should also be understood that the energy exchange device can exchange or interchange energy with several other air streams in closed loop and/or open loops, in the system or out of the system, also using water, air refrigerant, or other energy transferable fluid agents.

Closed Loop Heating Mode

[0040] Referring now to FIG. **1**B the basic components and the airflow path of the isolated closed loop thermodynamic process described above are shown in combination with a regeneration air stream and a process air stream in a thermodynamic heating mode, and the desiccant rotor is shown rotating through additional zones in communication with the regeneration and process air streams during the conditioning process. The components that are the same as described previously are assigned the same numerals of reference, but will not be described again in detail to avoid repetition. In the heating mode, the energy exchange device **10** is a heat exchange device capable of providing heat energy. Rotation of the desiccant rotor **9** is indicated by arrow **8** and the initial isolated zone of desiccant material for the isolated closed loop is identified as Z**1**.

[0041] It should be noted that the heat energy exchange device designated by numeral **10**, is designated by other numerals when referring to a specific type of heating or cooling energy exchange device, such as, for example, a refrigerant condenser coil or evaporator coil.

[0042] Desiccant zone Z**4** is in fluid communication with a heater device **41** which receives regeneration air **40** from a regeneration air intake. Desiccant zone Z**3** is in fluid communication with a process intake air **30**, and over which process air from a process air intake crosses to be processed by the system.

Method of Operation Closed Loop Heating Mode

[0043] As described above, the zone circulating fan **11** discharges air in an airflow path **13** that passes across the energy exchange device **10** where it is heated and exchanges its energy to achieve a desired vapor and temperature condition. The heated air stream **14** leaving the energy exchange device passes across the isolated zone Z**1** of the desiccant rotor **9** to directly condition the desiccant and moisture content. The desiccant material and content reacts to achieve an equilibrium state with the crossing air stream and the crossing air stream exits the isolated zone as air stream **12** having different (lower) temperature and vapor conditions as compared to the entering air. The air stream **12** leaving the isolated zone of the rotor returns to the intake of the zone circulating fan **11** in a continuous closed loop. The continuous closed loop is a continuous recirculation loop that provides a constant source of added heat energy to affect the desiccant temperature and vapor conditions.

[0044] In this particular process the desiccant material in zone Z**1** interchanges its energy in constant enthalpy equilibrium, and the air stream **12** leaving the zone Z**1** results in an adiabatic cooling and humidification effect. As a result of the continuous recirculation loop and constant source of added energy into the closed loop process the desiccant and its content, temperature and vapor conditions absorbs most of the added heat from the heat energy exchange device **10**.

[0045] As the desiccant rotor **9** rotates, the pre-conditioned desiccant material rotates out of zone Z**1** to the regeneration process zone Z**4**. The regeneration air flows from the air intake **40** enters the regeneration air heater **41**, exits as heated regeneration air in airflow path **42**, passes across the isolated regeneration zone Z**4**, and exits the other side of the isolated regeneration zone in air flow path **43** as regeneration exhaust air **45**.

[0046] The desiccant which is rotated from the pre-conditioning zone Z**1** to zone Z**4** has been pre-conditioned to contribute to the equilibrium and reaction rate and direction of the reaction of the desiccant with the heated air stream **42**, thereby accelerating the release of moisture in the crossing air stream **43** at zone Z**4**, and also reducing the amount of air required to be heated to provide an adequate regeneration process which results in regeneration energy savings. The regeneration process of zone Z**4** and its respective air stream enables the evacuation of unwanted moisture in the regeneration exhaust air **45**.

[0047] The desiccant material having reduced moisture and vapor content then rotates from regeneration zone Z**4** to the process zone Z**3**. The process air from the intake **30** flows through the process air zone Z**3** and exits the other side as process delivery air **31**. In this process the conditioned desiccant enables the wick material to adsorb moisture in its crossing air stream. The constant enthalpy and heat sink effect of the desiccant provides an adiabatic heating and re-heat effect and dehumidifies the crossing air stream which leaves as the process delivery or supply air **31**.

[0048] The usual adiabatic cooling effect of the regeneration process that typically occurs in a conventional open type system is not significant in the closed loop system, and the equilibrium achieved is facilitated by the direct heat transfer from the heat energy exchange device **10** at zone Z**1**.

[0049] In zone Z**1**, if the pre-conditioned desiccant material and content was elevated above the thermal and vapor pressure conditions different from the heated air stream **42** or desiccant conditions of zone Z**4**, then the desiccant and its content in reaction with the air will partially reverse direction as compared to a typical conventional regeneration air process.

[0050] In the conventional open type process the regeneration air is first heated, it then reacts with the desiccant content gradually and, after it achieves an equilibrium state, it releases its moisture content.

[0051] In the present process, pre-heating of the desiccant and content changes the rate of equilibrium and also the reaction equilibrium itself in the regeneration air stream. Unlike the conventional equilibrium state that usually occurs in the conventional process, the present process also make it possible to partially change the direction of the reaction.

[0052] Thus, the present process which pre-conditions the desiccant and its content changes the dynamics of the rate of equilibrium once rotated from a closed loop to an open flow regeneration process.

Closed Loop Cooling Mode

[0053] Referring now to FIG. **1**C, the components described above are shown arranged in a thermodynamic cooling mode, and the desiccant rotor is shown rotating through the zones during the conditioning process. The components that are the same as described previously are assigned the same numerals of reference, but will not be described again in detail to avoid repetition. In the cooling mode, the energy exchange device **20** is a cooling energy exchange device capable of removing heat energy, and is fluid communication with a zone Z**2** of the desiccant rotor **9**. Rotation of the desiccant rotor **9** is indicated by arrow **8**.

Method of Operation Closed Loop Cooling Mode

[0054] The zone circulating fan **21** discharges air in an airflow path **23** that passes across the cooling energy exchange device **20** where it is cooled to achieve a desired vapor and temperature condition. The cooled air stream **24** leaving the cooling energy exchange device passes across the isolated zone Z**2** of the desiccant rotor **9** to directly condition the desiccant and moisture content. The desiccant material and content reacts to achieve an equilibrium state with the crossing air stream and the crossing air stream exits the isolated zone as air stream **22** having higher temperature and vapor conditions as compared to the entering air. The air stream **22** leaving the isolated zone of the rotor returns to the intake of the zone circulating fan **21** in a continuous closed loop. The continuous closed loop is a continuous recirculation loop that provides a constant source of removed heat energy to affect the desiccant temperature and vapor conditions.

[0055] In this particular process the desiccant material in zone Z**2** interchanges its energy in constant enthalpy equilibrium, and the air stream **22** leaving the zone Z**2** results in an adiabatic heating and dehumidification effect. The continuous recirculation closed loop and constant absorption process and removal of heat energy from the closed loop process results in diminishing the desiccant temperature and vapor conditions.

[0056] The usual adiabatic heating effect of the process air that typically occurs in a conventional open type system is not as significant in the closed loop system, and the equilibrium achieved is facilitated by the direct absorption of heat energy at zone Z**2**.

[0057] The cooled and dehumidified desiccant material then rotates from regeneration zone Z**2** to the process air zone Z**3**. The process air from the intake **30** flows through the process air zone Z**3** and exits the other side as process delivery or supply air **31**. In this process the conditioned desiccant enables the wick material to adsorb moisture in its crossing air stream. The pre-conditioning of the desiccant accelerates the adsorption of moisture in the crossing air stream **30** which leaves as the process delivery or supply air **31**. The process delivery or supply air **31** is adiabatically heated prior to leaving.

[0058] In zone Z2, if the pre-conditioned desiccant material and content was lowered below the thermal and vapor pressure conditions of the process air stream **30**, then the desiccant and its content in reaction with the air will partially reverse direction as compared to a typical conventional process air process.

[0059] In the conventional open type process the process air is first cooled, it then reacts with the desiccant content gradually and, after it achieves an equilibrium state, it results in an average reaction of adsorption of its moisture content.

[0060] In the present process, pre-cooling of the desiccant and content changes the rate of equilibrium and also the reaction equilibrium itself in the crossing air stream. Unlike the conventional equilibrium state that usually occurs in the conventional process, the present process also makes it possible partially change the direction of the reaction.

[0061] Thus, the present process which pre-conditions the desiccant and its content changes the dynamics of the rate of equilibrium once rotated from the closed loop to the open flow regeneration process.

[0062] As the desiccant rotor **9** rotates, the pre-conditioned desiccant material rotates out of zone Z3 to the regeneration process zone Z4. The regeneration air flows from the air intake **40** enters the regeneration air heater **41**, exits as heated regeneration air in airflow path **42**, passes across the isolated regeneration zone Z4, and exits the other side of the isolated regeneration zone in air flow path **43** as regeneration exhaust air **45**.

Single Closed Loop to an Open Regeneration Air Stream

[0063] FIG. 2A shows, diagrammatically, an arrangement of the desiccant rotor system including the sensible heat energy exchange device and airflow paths for interchanging sensible energy from a single cooling closed thermodynamic loop to an open regeneration air stream.

[0064] In this arrangement, regeneration desiccant zone Z4 is in fluid communication with a regeneration heater **41** and suction side of a regeneration fan **47**. The regeneration intake air **40** flows through a sensible heat energy exchange device **25** and is directed via air flow path **46** to the regeneration heater **41**. Air leaving the regeneration heater **41** flows through the isolated regeneration desiccant zone Z4 of the rotor **9** via air flow path **42** and air leaving the desiccant zone Z4 enters the suction side of the regeneration fan **47** via air flow path **43** and is discharged by the regeneration fan as regeneration exhaust air **45**.

[0065] In the closed loop cycle and process, a separate isolated air stream **24** leaves the sensible heat exchange device **25** and passes across the isolated desiccant zone Z2 of the rotor **9** and leaves the isolated zone via air flow path **22** and enters the suction side of the closed loop circulating fan **21**. The air discharged from the circulating fan via air flow path **23** also enters the sensible heat exchange device **25** as a separate alternate crossing air stream **23** and exits the device as cooler air stream **24** and continuously re-circulates.

[0066] The process air from the process air intake **30** flows through the process air desiccant zone Z3 of the rotor and leave as process air delivery air **31**.

Method of Operation Single Closed Loop to an Open Regeneration Air Stream

[0067] Air from the regeneration intake air **40** enters first into the sensible heat exchanger device **25** where interchanges its sensible energy with the alternate crossing air stream **23** of the closed loop. As a result of the temperature differential between the crossing air streams **40** and **23**, the crossing air **23** is cooled in some equilibrium aspect and discharged via air path **24**.

[0068] This process re-uses the remaining pre-conditioned desiccant sensible energy heat sink capacitance, in part, by heating the air stream **46**. The air in air stream **46** contains recovered energy and then crosses the regeneration heater **41** which adds and augments the sensible heat energy into its leaving air stream **42**. This air then crosses the isolated desiccant regeneration zone Z4 where constant enthalpy equilibrium energy is interchanged from the desiccant and moisture content in zone Z4. The regeneration air **43** leaving zone Z4 is humidified and cooled adiabatically. The air is then discharged by the regeneration fan **47** as regeneration exhaust air **45**.

[0069] The separate air stream **23** of the closed loop which also crosses the sensible heat exchanger **25**, leaves as cooler air in stream **24**. The interchanged sensible energy occurring in the heat exchanger **25** which causes the heating of the air stream **46** also simultaneously causes a cooling effect of the air stream **23**. The air stream **24** of the closed loop leaving the sensible heat exchanger **25** enters the isolated desiccant zone Z1 of the rotor **9** where the desiccant material interchanges its sensible energy with the crossing air to pre-condition its heat capacitance and content. The air leaving the isolated desiccant zone Z1 absorbs part of the elevated temperature heat capacitance and content of the desiccant. The re-heated air leaves as air path **22** to the intake of the closed loop circulating fan **21** and is discharged via air path **23** and enters the sensible heat exchanger **25** and continuously re-circulates.

[0070] In this aspect of the process, the sensible energy is interchanged through the heat exchanger **25** between the entering air stream **40** and the air stream from the closed loop **23** into sensible energy and temperature equilibrium. Thus, the desiccant in zone Z1 is cooled and the interchanged energy results in the effect of heating the adjacent air stream **46**.

[0071] Therefore, the elevated desiccant heat capacitance and content from the isolated zone Z1 is cooled through the effect of the sensible heat exchanger **25** and its crossing air stream **40**. The heat recovery process from the sensible heat exchanger **25** results in pre-conditioning of the desiccant material in zone Z1. Sensible energy is removed from the desiccant in zone Z1 and is recovered in series into the air regeneration air stream **46**.

[0072] The energy exchange device **25** can be any type of apparatus to remove, recuperate, recover or exchange or interchange sensible or latent heat energy and moisture content in its crossing air stream. For example, such devices as: refrigerant evaporator, water or radiator type coils, thermoelectric cooling, sensible energy exchanger, plated type, second rotor, or heat pipe apparatus. In this particular arrangement, the energy exchange device **25** provides an air cooling process capable of removing heat energy in the closed loop.

[0073] In this particular process the desiccant material in zone **Z1** interchanges its energy in constant enthalpy equilibrium, and the air stream **22** leaving the zone **Z2** results in an adiabatic heating and dehumidification effect. The continuous recirculation closed loop and constant absorption process and removal of heat energy from the closed loop process results in diminishing the desiccant temperature and vapor conditions.

[0074] The usual adiabatic heating effect of the process air that typically occurs in a conventional open type system is not significant in the closed loop system, and the equilibrium achieved is facilitated by the direct absorption of heat energy at zone **Z1**.

[0075] The cooled and dehumidified desiccant material then rotates from zone **Z1** to the to the separate process air zone **Z3** and the desiccant material and remaining content from zone **Z4** rotates to the closed loop zone **Z1**

[0076] The process air from the intake **30** flows through the process air zone **Z3** and exits the other side as process delivery or supply air **31**. In this process the conditioned desiccant enables the wick material to adsorb moisture in its crossing air stream. The pre-conditioning of the desiccant accelerates the adsorption in the crossing air stream **30** which leaves as the process delivery or supply air **31**. The process delivery or supply air **31** could be also be adiabatically heated and also could be re-cooled through the desiccant heat sink effect and energy exchange prior to leaving as the process delivery or supply air **31**.

[0077] If the pre-conditioned desiccant material and content was lowered below the thermal and vapor pressure conditions of the process air stream **30**, then the desiccant and its content in reaction with the air will partially reverse direction as compared to a typical conventional process air process.

[0078] In the conventional open type process the process air is first cooled, it then reacts with the desiccant content gradually and, after it achieves an equilibrium state, it results in an average reaction of adsorption of its moisture content.

[0079] In the present process, pre-cooling of the desiccant and moisture content changes the rate of equilibrium and also the reaction equilibrium itself in the crossing air stream. Unlike the conventional equilibrium state that usually occurs in the conventional process, the present process also make it possible to partially change the direction of the reaction.

[0080] Thus, the present process which pre-conditions the desiccant and its moisture content changes the dynamics of the rate of equilibrium once rotated from the closed loop to the open flow regeneration process.

[0081] As the desiccant rotor **9** rotates, the pre-conditioned desiccant material rotates out of zone **Z3** to the regeneration process zone **Z4**. The desiccant which is rotated from the process air zone **Z3** to zone **Z4** has been pre-conditioned to achieve moisture content, temperature and vapor conditions which are determined to contribute to the equilibrium and reaction rate and direction of the reaction of the desiccant with the crossing air stream, thereby facilitating its ability to react in a constant enthalpy interchangeable energy adiabatic cooling process, and reduces the amount of air required to be heated to provide an adequate regeneration process.

[0082] The combined heat exchanger **25** and regeneration heater **25** heats the entering air **40** and discharges the elevated temperature air into the rotor desiccant zone **Z4**. The conditioning of the air stream **42** enables the desiccant and moisture content to react with its crossing air stream in a constant enthalpy interchangeable energy adiabatic cooling process and results in a humidified and cooling effect on the air **43** leaving the desiccant zone **Z4** and the regeneration process of zone **Z4** and its air streams enable evacuation of unwanted moisture in the regeneration exhaust air **45**.

Combined Heating and Cooling with Two Closed Loops

[0083] FIG. **2B** is a diagrammatic view illustrating an arrangement of the desiccant rotor system components and airflow paths and process utilizing both, heating and cooling closed thermodynamic loops simultaneously. The closed loops are the same as the closed loops shown and described above with reference to FIGS. **1B** and **1C**, and are assigned the same numerals of reference, but will not described again in detail to avoid repetition.

[0084] In the first closed loop, the energy exchange device **10** is a heat exchange device capable of providing heat energy and the initial isolated zone of desiccant material for the isolated closed loop is identified as **Z1**. The zone circulating fan **11** discharges air in an airflow path **13** that passes across the energy exchange device **10** where it is heated and exchanges its energy to achieve a desired vapor and temperature condition. The heated air stream **14** leaving the energy exchange device passes across the isolated zone **Z1** of the desiccant rotor **9** to directly condition the desiccant and moisture content. The desiccant material and content reacts to achieve an equilibrium state with the crossing air stream and the crossing air stream exits the isolated zone as air stream **12** having higher temperature and vapor conditions as compared to the entering air. The air stream **12** leaving the isolated zone of the rotor returns to the intake of the zone circulating fan **11** in a continuous closed loop that provides a constant source of added heat energy to affect the desiccant temperature and vapor conditions.

[0085] As the desiccant rotor **9** rotates, the pre-conditioned desiccant material rotates out of zone **Z1** to the regeneration process zone **Z4**. The regeneration air flows from the air intake **40** enters the regeneration air heater **41**, exits as heated regeneration air in airflow path **42**, passes across the isolated regeneration zone **Z4**, and exits the other side of the isolated regeneration zone in air flow path **43** as regeneration exhaust air **45**.

[0086] The preconditioned desiccant material rotates out of zone **Z4** to the zone **Z2** which is in fluid communication with the second closed loop. In the second closed loop, the energy exchange device **20** is a cooling energy exchange device capable of removing heat energy, and is fluid communication with zone **Z2** of the desiccant rotor **9**. The zone circulating fan **21** discharges air in an airflow path **23** that passes across the cooling energy exchange device **20** where it is cooled to achieve a desired vapor and temperature condition. The cooled air stream **24** leaving the cooling energy exchange device passes across the isolated zone **Z2** of the desiccant rotor **9** to directly condition the desiccant and moisture content. The desiccant material and content reacts to achieve an equilibrium state with the crossing air stream and the crossing air stream exits the isolated zone as air stream **22** having higher temperature and vapor conditions as compared to the entering air. The air stream **22** leaving the isolated zone of the rotor returns to the intake of the zone circulating fan **21** in a continuous closed loop that provides a constant source of removed heat energy to affect the desiccant temperature and vapor conditions.

[0087] The preconditioned desiccant material rotates out of zone Z**2** to the process air desiccant zone Z**3** which is in fluid communication with the process air intake **30**, and process air from the process air intake crosses over the desiccant zone Z**3** and exits the other side as process delivery or supply air **31**, and as the desiccant rotor **9** continues to rotate, the desiccant material rotates out of zone Z**3** to return to the isolated desiccant zone Z**1**.

[0088] The heating and cooling process of the first and second closed loops and the regeneration process and conditioning of the process delivery or supply air **31** can occur simultaneously.

[0089] As stated above, this particular arrangement is a combination of the arrangements of FIGS. **1**B and **1**C, and it should be understood, that the method of operation of the two closed loop arrangement is the same as described previously with regard to FIGS. **1**B and **1**C, but combined and occur simultaneously. For a more detailed description of the operation, the reader may refer to the previous method of operation of both Figures. It should also be understood, that the present system may utilize more than one closed loop for providing heat energy and more that one closed loop for removing heat energy operating simultaneously.

Combined Heat and Cool with Two Closed Loops and Rotor Heat Exchange Device

[0090] FIG. **3**A is a diagrammatic view illustrating an arrangement of the desiccant rotor system components including a second rotor or sensible heat energy recovery device and airflow paths for interchanging and recovering energy from dual zone closed thermodynamic loops. The closed loops are the same as described above and in FIGS. **1**B and **1**C in combination with a sensible heat energy exchange device and an open regeneration air stream, as described in FIG. **2**B. The components that are the same as shown and described above and with reference to FIGS. **1**B, **1**C, and **2**B, are assigned the same numerals of reference, but will not described again in detail to avoid repetition.

[0091] In this arrangement, the energy exchange device is a desiccant rotor energy exchange device **50** having a heating regeneration desiccant zone **10** in fluid communication with the closed heating loop (the inner loop) which functions similar to the heat exchanger **10** of FIG. **1**B and a cooling regeneration desiccant zone **20**) in fluid communication with the closed cooling loop (the outer loop) which functions similar to the cooling energy exchange device **20** of FIG. **1**C, wherein the desiccant zones of the rotor energy exchange device **50** provide heating and cooling energy exchange.

[0092] In the first or outer closed loop, the zone circulating fan **21** draws air across the isolated desiccant zone Z**1** of the desiccant rotor **9** and discharges it in an airflow path **23** that passes across the heating regeneration desiccant zone **10** of the rotor energy exchange device **50** to achieve a desired vapor and temperature condition, leaves the desiccant zone **10** of the rotor energy exchange device **50** and returns across the isolated zone Z**1** of the desiccant rotor **9** in a continuous closed loop. The first or outer continuous closed loop is a continuous recirculation loop that provides a constant source of additional heat energy to affect the desiccant temperature and vapor conditions.

[0093] As the desiccant rotor **9** rotates, the pre-conditioned desiccant material rotates out of zone Z**1** to the regeneration process zone Z**4**. Regeneration desiccant zone Z**4** of the desiccant rotor **9** is in fluid communication with a regeneration heater device **41** and suction side of a regeneration fan **47**. The regeneration intake air **40** flows through the heater device **41** via air flow path **42** through the isolated regeneration desiccant zone Z**4** of the rotor **9** and air leaving the desiccant zone Z**4** enters the suction side of the regeneration fan **47** via air flow path **43** and is discharged by the regeneration fan as regeneration exhaust air **45**.

[0094] As the desiccant rotor **9** rotates from the regeneration desiccant zone Z**4** to zone Z**2** the regenerated desiccant material is in the path of the second closed loop (the inner loop). In the second or inner closed loop, the zone circulating fan **11** draws air across the isolated desiccant zone Z**2** of the desiccant rotor **9** and discharges it in an airflow path **13** that passes across the pre-cooling regeneration desiccant zone **20** of the rotor energy exchange device **50** to achieve a desired vapor and temperature condition, leaves the desiccant zone **20** of the rotor energy exchange device **50** and returns across the isolated zone Z**2** of the desiccant rotor **9** in a continuous closed loop that provides constant heat energy removal to affect the desiccant temperature and vapor conditions.

[0095] The desiccant rotor **9** then rotates from the desiccant zone Z**2** to zone Z**3** where the regenerated and pre-cooled desiccant material is in the path of the process air desiccant zone Z**3** which is in fluid communication with the process air intake **30**, and process air from the process air intake crosses over the desiccant zone Z**3** and exits the other side as process delivery or supply air **31**. As the desiccant rotor **9** continues to rotate, the desiccant material rotates out of zone Z**3** to return to the isolated desiccant zone Z**1**.

[0096] The heating and cooling process of the first and second closed loops and the regeneration process and conditioning of the process delivery or supply air **31** can occur simultaneously. In other words, as the regeneration sequence occurs in the desiccant rotor regeneration zone Z**4** another process occurs in isolated zone Z**2** and zone Z**1**. In these two zones, two separate air streams exist and interchange energy through the regeneration zones **10** and **20** of the second desiccant rotor energy exchange device **50**.

[0097] As the second desiccant rotor energy exchange device **50** rotates, the cooled air stream **23** from zone Z**1** of the rotor **9** passes across the regeneration zone **10** of the rotor **50**, and is re-heated by the desiccant material which was regenerated at zone **20** by the heated air stream **13** from zone Z**2** of the rotor **9**.

[0098] The desiccant in the regeneration zone **10** of the desiccant rotor energy exchange device **50** is regenerated and provides the energy to re-heat and the cooled air stream **23** which crosses the regeneration zone **10** of the desiccant rotor energy exchange device. Optionally, depending on the rotor type selection, some latent interchangeable energy could also occur to permit latent energy exchange between both air streams **23** and **13**. This would cause the leaving air **24** not only to be heated with sensible energy recovery but also through the ability of its desiccant to also have an adiabatic heating effect caused by the interchangeable energy exchange of the captured moisture content into its desiccant wick material. This captured moisture content also reduces moisture in proportion to its crossing air stream **24** and becomes part of the energy equilibrium entering the isolated zone Z**1** of the desiccant rotor **9**.

[0099] The moisture reset feature that occurs between the zones Z**2** and zone Z**1** of the rotor **9** and the regeneration zones **20** and **10** of the of the second desiccant rotor energy exchange device **50** enables the desiccant content and moisture conditions in zone Z**1** to be reduced in total heat capacitance. The reduced heat capacitance diminishes the usual unwanted re-heating effect of the desiccant material and content when the rotor **9** is rotated from zone Z**2** to the process zone Z**3** and the heat of the processed air delivery or supply stream **31** is diminished due to the diminished heat sink energy the rotated desiccant and content. The latent heat capability of the second desiccant rotor energy exchange device **50** enables extra capability of energy exchange. Thus, augmented adiabatic sensible and cooling desiccant effect is interchanged for either the dissipation or capturing of moisture. This reset process augments the total effective cooling.

[0100] As stated above, this particular arrangement is a combination of the arrangements of FIGS. **1**B, **1**C, and **2**B, and it should be understood, that the method of operation of the closed loop arrangement and the regeneration process and conditioning of the process delivery or supply air **31** is the same as described previously with regard to FIGS. **1**B, **1**C, and **2**B, but combined and occur simultaneously. For a more detailed description of the operation, the reader may refer to the previous method of operation of those figures. It should also be understood, that the present system may utilize more than one closed loop for providing heat energy and more that one closed loop for removing heat energy operating simultaneously.

Combined Heat and Cool with Two Closed Loops and Sensible Heat Exchange Device

[0101] FIG. **3**B is a diagrammatic view illustrating an arrangement of the desiccant rotor system similar to FIG. **3**A utilizing dual closed loops as described in FIGS. **1**B, **1**C, and **2**B in combination with a sensible heat energy exchange device and an open regeneration air stream as described in FIG. **2**A for interchanging sensible energy from one dual zone closed thermodynamic loop to the open regeneration air stream and directly conditioning the desiccant in a second one of the dual zone closed loops. The components that are the same as shown and described above and with reference to FIGS. **1**B, **1**C, **2**A, **2**B and **3**A, are assigned the same numerals of reference, but will not described again in detail to avoid repetition.

[0102] In the first closed loop, the zone circulating fan **11** draws air across the isolated desiccant zone Z**1** of the desiccant rotor **9** and discharges it in an airflow path **13** that passes across the heat energy exchange device **10** where it is heated to achieve a desired higher vapor and temperature condition, and the heated air leaves the heat energy exchange device **10** in air flow path **14**, crosses the isolated zone Z**1** of the desiccant rotor **9**, and returns to the suction side of the zone circulating fan **11** in a continuous closed loop that provides a constant source of additional heat energy to affect the desiccant temperature and vapor conditions.

[0103] In this arrangement, regeneration desiccant zone Z**4** is in fluid communication with a regeneration heater device **41** and suction side of a regeneration fan **47**. The regeneration intake air **40** flows through a sensible heat energy exchange device **25** and is directed via air flow path **46** to the regeneration heater **41**. Air leaving the regeneration heater **41** flows through the isolated regeneration desiccant zone Z**4** of the rotor **9** via air flow path **42** and air leaving the desiccant zone Z**4** enters the suction side of the regeneration fan **47** via air flow path **43** and is discharged by the regeneration fan as regeneration exhaust air **45**.

[0104] In the second closed loop, the zone circulating fan **21** draws an isolated air stream **22** through the sensible heat exchange device **25**, across the isolated desiccant zone Z**2** of the rotor **9**, and discharges it as a crossing air stream **23** back through the sensible heat exchange device **25** and across the isolated desiccant zone Z**2** of the rotor **9** and to the suction side of the closed loop circulating fan **21**. Thus, the air discharged from the circulating fan via air flow path **23** also enters the sensible heat exchange **25** as a separate alternate crossing air stream **23** and exits the device as a cooler air stream **24**.

[0105] The process air from the process air intake **30** flows through the process air desiccant zone Z**3** of the rotor and leave as process air delivery or supply air **31**.

[0106] When the desiccant material is in zone Z**1** it interchanges its energy in constant enthalpy equilibrium, facilitated by the direct absorption of heat energy from the air stream of the closed loop.

[0107] As the desiccant rotor **9** rotates, the pre-conditioned desiccant material rotates out of zone Z**1** to the regeneration process zone Z**4**. The regeneration air **40** enters into the sensible heat exchange device **25** where it interchanges its sensible energy with the adjacent crossing air stream **23** of the closed loop and the air leaving the regeneration heater **41** flows through the isolated regeneration desiccant zone Z**4** of the rotor **9** via air flow path **42** and air leaving the desiccant zone Z**4** enters the suction side of the regeneration fan **47** via air flow path **43** and is discharged by the regeneration fan as regeneration exhaust air **45**. The temperature and moisture conditions of the desiccant material pre-conditioned in zone Z**1** accelerate the release of moisture in the crossing air stream **43**. If the desiccant material and content pre-conditioned in zone Z**1** was elevated above the condition of the heated air stream **42** then the desiccant reaction would reverse direction in some aspect and add to the release and acceleration rate of moisture in its crossing air stream **43**. Depending upon the pre-conditioning of the desiccant in zone Z**1** the leaving air **43** could be adiabatically cooled or heated through the desiccant heat sink effect and energy. The regeneration zone Z**4** and open and closed loop air streams also facilitate the evacuation of unwanted moisture in the regeneration exhaust air **45**.

[0108] The desiccant rotor **9** rotates from zone Z**4** to the zone Z**2** and the augmented and elevated desiccant material from zone Z**4** is in communication with regeneration closed loop zone Z**2**. The process in the second closed loop uses the heat sink capacitance, of the zone Z**2**, to heat the air stream **46** through the adjacent side of the heat exchanger **25** as described in FIG. **1**C. The air in air stream **46** contains recovered energy and then crosses the regeneration heater **41** which adds and augments the sensible heat energy into its leaving air stream **42** which crosses the isolated desiccant regeneration zone Z**4** where constant enthalpy equilibrium energy is interchanged from the desiccant and moisture content in zone Z**4**. The regeneration air **43** leaving zone Z**4** is humidified and cooled adiabatically. The air is then discharged by the regeneration fan **47** as regeneration exhaust air **45**.

[0109] As result of temperature differential the crossing air **23** is heated at the heat energy exchange device **25** discharged via air path **24**. This process re-uses the remaining desiccant sensible energy heat sink capacitance and pre-condition in part by heating the air stream **46**. The air stream **46** crossing the regeneration heater **41** adds and augments the sensible heat energy into the leaving air stream **42** which then crosses the desiccant regeneration isolated zone Z**4** and interchanges its energy in constant enthalpy equilibrium. The air **43** leaving zone Z**4** is humidified and cooled adiabatically and discharged as regeneration exhaust air **45**.

[0110] The desiccant rotor **9** then rotates from the desiccant regeneration zone Z**2** to zone Z**3** where the regenerated and pre-cooled desiccant material is in the path of the process air desiccant zone Z**3** which is in fluid communication with the process air intake **30**, and process air from the process air intake crosses over the desiccant zone Z**3** and exits the other side as process delivery or supply air **31**. Pre-conditioning of the desiccant material and moisture content accelerates the adsorption of moisture in the crossing air stream **30**. As the desiccant rotor **9** continues to rotate, the desiccant material rotates out of zone Z**3** to return to the isolated desiccant zone Z**1**.

[0111] This process in particular reduces the heat sink and transferable energy usually occurring in typical conventional desiccant rotor applications and significantly diminishes the desiccant re-heat effect in the process delivery or supply air stream that often occurs.

[0112] The heating and cooling process of the first and second closed loops and the regeneration process and conditioning of the process delivery or supply air **31** can occur simultaneously. In other words, as the regeneration sequence occurs in the desiccant rotor regeneration zone Z**4** another process occurs in isolated zone Z**2** and zone Z**1**.

[0113] As stated above, this particular arrangement is a combination of the arrangements of FIGS. **1**B, **1**C, and **2**A, **2**B and operating in a manner similar to that described in FIG. **3**A, which have been described above. For a more detailed description of the operation, the reader may refer to the previous method of operation of those figures. It should also be understood, that the present system may utilize more than one closed loop for providing heat energy and more that one closed loop for removing heat energy operating simultaneously.

Combined Heat and Cool with Two Closed Loops and Refrigeration System

[0114] FIG. **4**A is a diagrammatic view illustrating an arrangement of the desiccant rotor system similar to FIG. **3**A utilizing dual closed loops as described above and in FIGS. **1**B and **1**C in combination with a refrigeration system for added energy transfer capability. The components that are the same as shown and described above and with reference to FIGS. **1**B, **1**C, and **3**A, are assigned the same numerals of reference, but will not described again in detail to avoid repetition.

[0115] In this arrangement, the heat energy exchange device is a condenser coil **60** disposed in heat exchange relation in the closed heating loop (the outer loop) and the cooling energy exchange device is an evaporator coil **70** disposed in heat exchange relation in the closed cooling loop (the inner loop).

[0116] In the first or outer closed loop, the zone circulating fan **21** draws air across the isolated desiccant zone Z**1** of the desiccant rotor **9** and discharges it in an airflow path **23** that passes across the condenser coil **60** to achieve a desired vapor and temperature condition, leaves the condenser coil **60** in air flow path **24**, and returns across the isolated zone Z**1** of the desiccant rotor **9** in a continuous closed loop. The first or outer continuous closed loop is a continuous recirculation loop that provides a constant source of additional heat energy to affect the desiccant temperature and vapor conditions.

[0117] As the desiccant rotor **9** rotates, the pre-conditioned desiccant material rotates out of zone Z**1** to the regeneration process zone Z**4**. The regeneration desiccant zone Z**4** of the desiccant rotor **9** is in fluid communication with the suction side of the regeneration fan **47** and the regeneration fan draws regeneration intake air **40**, through an optional refrigerant condenser **61**, which leaves in air flow path **51** that flows through an optional heater device **41** and exits via air flow path **42** through the isolated regeneration desiccant zone Z**4** and is discharged by the regeneration fan as regeneration exhaust air **45**. In this particular application, regeneration intake air may be any pre-conditioned air or outside air. Outdoor air **40** in a separate side or bypass system crosses an optional condenser coil **62** and is discharged through a damper **110** or fan as discharge air **53**. Optionally, the discharge air **53** may be re-joined with the regeneration exhaust air **45** and may also be connected with the regeneration fan **47**.

[0118] As the desiccant rotor **9** rotates, the pre-conditioned desiccant material rotates out of regeneration process zone Z**4** to the isolated desiccant zone Z**2** which is in communication with the second (inner) closed loop. In the second or inner closed loop, the zone circulating fan **11** draws air across the isolated desiccant zone Z**2** of the desiccant rotor **9** and discharges it in an airflow path **13** that passes across evaporator coil **70** to achieve a desired vapor and temperature condition, leaves the evaporator coil **70**, and returns across the isolated zone Z**2** of the desiccant rotor **9** in a continuous closed loop that provides constant heat energy removal to affect the desiccant temperature and vapor conditions.

[0119] The desiccant rotor **9** then rotates from the desiccant regeneration zone Z**2** to zone Z**3** where the regenerated and pre-cooled desiccant material is in the path of the process air desiccant zone Z**3** which is in fluid communication with the intake process air **30**, and process air **30** crosses over an optional evaporator coil **71** and exits in air stream **55** which crosses the isolated desiccant zone Z**3** of the rotor **9** and is discharged as air stream **56** which crosses another optional evaporator coil **72**, and is discharged as process delivery or supply air **31**. As the desiccant rotor **9** continues to rotate, the desiccant material rotates out of zone Z**3** to return to the isolated desiccant zone Z**1**.

[0120] FIG. **4**B is a diagrammatic view of the piping and refrigeration coils of the refrigeration system of FIG. **4**A in a series refrigeration coil arrangement. In this arrangement, the discharge port of a compressor **80** is connected via conduit **82** to the intake side of the optional condenser coil **62** in the outdoor air regeneration bypass system, and its discharge side is connected via conduit **87** to the intake of the optional refrigerant condenser coil **61** in the regeneration air system. The discharge side of the condenser coil **61** is connected via conduit **88** to the intake of the condenser coil **60** in the first (outer) closed loop. The discharge of the condenser coil **60** is connected via conduit **85** to one port of an expansion valve **81** and the other port of the expansion valve is connected via conduit **86** to the evaporator coil **70** in the second (inner) closed loop. The discharge of the evaporator coil **70** is connected via conduit **89** to the intake of the optional evaporator coil **71** in the process air stream. The discharge of the optional evaporator coil **71** is connected via conduit **99** to the intake of the second optional evaporation coil **72** in the process air stream. The discharge of the second optional evaporation coil **72** is connected via conduit **83** to the suction port of the compressor **80**.

[0121] FIG. **4**C is a diagrammatic view of the piping and refrigeration coils of the refrigeration system of FIG. **4**A in a parallel refrigeration coil arrangement. In this arrangement, the discharge port of the compressor **80** is connected via conduit **82** to the intake side of the coils **62**, **61** and **60**. These discharge side of the coils are connected via conduit **84** to one port of the expansion valve **81** and the other port of the expansion valve is connected via conduit **86** to the intake side of the coils **70**, **71** and **72**. The discharge side of the coils **70**, **71** and **72** are connected via conduit **83** to the suction port of the compressor **80**.

Method of Operation Heat and Cool with Two Closed Loops and Refrigeration System

[0122] The air flow paths have been discussed above and will not be described again in detail to avoid repetition. In the refrigerant compression closed cycle of the refrigeration system, the compressor **80** compresses refrigerant gas to increases its pressure and temperature in an isentropic adiabatic process. The refrigerant is then passed through the condenser coils **62**, **61**, **60** where the superheated compressed refrigerant dissipates its heat to the crossing air stream and the refrigerant is condensed into a high-pressure liquid. The condenser coils reject the evaporator heat load, the evaporator superheat, and the heat of compression generated by the compressor. The refrigerant after dissipating its heat through the condensing coils approaches the metering device **81** where the pressure of the liquid is reduced to a lower evaporator pressure condition. When the liquid is expanded into the evaporator coils through the output orifice of the metering device **81**, the temperature and pressure of the refrigerant liquid is reduced. Although only one expansion valve is shown in the drawings, it should be understood that an expansion valve may be installed at each evaporator coil.

[0123] As mentioned above, the metering device or expansion valve or valves restrict the high-pressure liquid and creates a reverse refrigerant adiabatic effect, after which, the refrigerant is discharged or suctioned to the evaporator coil or evaporator coils **70**, **71**, **72** at lower refrigerant temperature and pressure conditions, which enable the evaporator coils to absorb heat from the crossing air that is forced through the coil by the evaporator fan. The air exiting the evaporator coils is discharged as cool air and the refrigerant absorption process changes the refrigerant from liquid-gas to gas, which is then suctioned back to the compressor to complete the closed cycle.

[0124] Referring again to FIG. **4**A, the outdoor air **40**, flows across the optional condenser coil **62**. The compressor dissipates its refrigerant energy transferring heat into the crossing air **53** and the air **53** leaving the condenser coil **62** is heated. This heated air is either suctioned by the fan and or controlled by a damper type device represented as **110**.

[0125] The regeneration intake air **40**, which may be an alternate air stream or outdoor air crosses the second condenser coil **61** and/or coil **62** which dissipate their heat into the crossing air stream which leaves in air flow path **51** that flows through the optional heater device **41** where it is additionally heated and exits via air flow path **42** through the isolated regeneration desiccant zone Z**4** where it interchanges its energy with the desiccant and leaves the rotor as regenerated exhaust air **43**. This air interchanges its energy through an adiabatic cooling effect and moisture is also dissipated also in the crossing air **43**. The air stream **43** is then discharged by the regeneration fan as regeneration exhaust air **45**.

[0126] Simultaneously as this sequence occurs in the desiccant rotor regeneration zone Z**4** another process occurs in isolated desiccant zones Z**2** and Z**1**. In these zones, two separate air streams exist and interchange refrigerant energy through the evaporator coil **70** and condenser coil **60** of the refrigeration system.

[0127] In the first or outer closed loop, the air stream **14** enters the isolated desiccant zone Z**1** of the desiccant rotor **9** where the desiccant has been preconditioned by the process air stream prior to rotation to have a lowered temperature and elevated moisture content. The crossing air **14** flows through the isolated rotor zone Z**1**, which gradually heats the desiccant. This energy exchange also results in a cooling effect caused, in part, by the heat sink effect and also caused by an adiabatic cooling effect, thereby releasing some moisture in the air stream leaving the isolated desiccant zone Z**1**. This air enters the intake of the re-circulating fan **11** and the cooled air **13** is discharged to enter the condenser coil **60**. As previously mentioned the condenser coil **60** dissipates its refrigerant energy to the crossing air stream **13**, thereby heating the air stream **14** leaving the condenser coil. The heated air stream **14** re-enters the isolated desiccant zone Z**1** of the rotor **9** in the recirculating closed loop process described above.

[0128] In the second (inner) closed loop, the air stream **24** crosses the isolated zone Z**2** of the rotor **9**. The desiccant in this isolated zone has been preconditioned from the regeneration air stream at desiccant zone Z**4** prior to rotation. In this zone, the desiccant temperature is elevated and substantially dry. The crossing air **24** cools the desiccant material, and the air **23** leaving zone Z**2** is heated as a result of the energy exchange process. The heated air **23** is then discharged by the zone circulating fan **21** to cross the evaporator coil **70** and re-enters the isolated desiccant zone Z**4** of the rotor **9** in the closed loop process described above.

[0129] The transferred and added energy caused by the isolated loops and refrigeration energy exchanges results in the transport of sensible energy from the isolated zone Z**2** to isolated zone Z**1**. As the desiccant is rotated from zone Z**1** to zone Z**4**, the reset of temperature and vapor conditions facilitate preparing it for the next regeneration process.

[0130] The heat transfer feature between the zones Z**2** and Z**1** enables the desiccant and moisture conditions to be reduced in total heat capacitance which diminishes the unwanted re-heat effect of the desiccant when the rotor **9** is rotated from zone Z**2** to the process zone Z**3**. The process intake air **30** flows across the optional evaporator coil **71** absorbs energy through the crossing air stream and the leaving air **55** is cooled before entering zone Z**3** as result of the refrigeration evaporating process and facilitates the absorption of moisture as it crosses zone Z**3**. The air stream leaving zone Z**3** and discharged as process delivery or supply air **31** is also diminished in heat due to the heat sink and the effect from the rotated pre-conditioned desiccant from zone Z**2** . This heat transfer process augments the total effective cooling. The air **56** leaving zone Z**3** could be re-cooled by the second optional evaporator coil **72** to re-capture this heat effect or simply cool the leaving delivery or supply air **31**.

[0131] It should be understood, that the refrigeration system may be provided without the optional condenser coils **62** and/or **61** and the evaporator coils **72** and/or **71**, or may utilize any number of coils connected in a series or parallel sequence or combination thereof. It should also be understood that the condenser coils may be combined as one device and/or may be controlled through either its crossing air volume and/or valves may be provided to redirect the refrigerant heat toward other condenser coils.

Heat and Cool with Two Closed Loops, Refrigeration System, and Process Air Stream Bypass

[0132] FIG. **5** is a diagrammatic view illustrating a modification of FIG. **4** wherein the process air stream has a bypass air path that bypasses the desiccant zone Z3 of the desiccant rotor **9**. The air flow paths, the arrangement of the components, and the series refrigeration coil arrangement are the same as described above with reference to FIG. **4**A, and are assigned the same numerals of reference, but will not described again in detail to avoid repetition. The optional evaporator coil **72** described in FIG. **4**A has been removed

[0133] In this modification, the intake process air **30** first crosses the optional evaporator coil **71** and the air **55** leaving the evaporator coil crosses through the isolated zone Z3 of the rotor **9** and is discharged via air stream **56** as the process delivery or supply air **31**. The air **55** leaving the evaporator coil can also flow through an optional bypass damper **93** via ducting **91** to bypass the zone Z3 and rejoin with the air stream **56** via ducting **92** to mix with the air stream **56** and be discharged as the process delivery or supply air **31**. This optional bypass air path bypasses the rotor zone Z3 to controls the sensible cooling effect caused by the optional evaporator coil **71** and/or to diminish the dehumidification effect caused by the desiccant zone Z3.

Combined Cooling and Dehumidification with One Closed loop and Refrigeration System

[0134] FIG. **6**A is a diagrammatic view illustrating an arrangement of the desiccant rotor system utilizing a closed loop similar to FIG. **1**B in combination with a refrigeration system, wherein the process intake air crosses the desiccant rotor twice, first through a regeneration process, after crossing a dehumidifying refrigerant cooling coil, and re-crossing the rotor a second time as process air to be discharged as supply air. The components that are the same as described previously are assigned the same numerals of reference, but will not be described again in detail to avoid repetition.

[0135] In this arrangement it should be noted that rotation of the desiccant rotor **9** indicated by arrow **8** is shown to be in a clockwise direction. In the first closed loop cycle and process, the closed loop circulating fan **11** conducts a separate isolated air stream in a flow path **13** across a condenser coil **60** which dissipates its refrigerant energy to the crossing air stream, thereby heating the air stream, and the heated air stream **14** crosses the isolated desiccant zone Z1 of the rotor **9** and returns to the suction side of the circulating fan in a continuous closed loop that provides constant added heat energy to affect the desiccant temperature and vapor conditions.

[0136] The process intake air **30**, which may be any preconditioned air or outside air, flows through the desiccant zone **Z4** of the rotor, leaves the rotor as regenerated exhaust air **56** which crosses an evaporator coil **72**, leaves the evaporator coil in air flow path **96** which then crosses desiccant zone Z3 of the rotor and is discharged as process delivery or supply air **31**.

[0137] Outdoor air **52** in a separate air flow path or bypass system crosses an optional condenser coil **62** and is discharged as discharge air **53**.

[0138] FIG. **6**B is a diagrammatic view of the piping and refrigeration coils of the refrigeration system of FIG. **6**A in a series refrigeration coil arrangement. In this arrangement, the discharge port of a compressor **80** is connected via conduit **82** to the intake side of the optional condenser coil **62** in the outdoor air flow path or bypass system, and its discharge side is connected via conduit **87** to the intake of the optional refrigerant condenser coil **60** in the closed loop regeneration air system. The discharge of the condenser coil **60** is connected via conduit **85** to one port of an expansion valve **81** and the other port of the expansion valve is connected via conduit **89** to the intake of the optional evaporator coil to the intake of the optional evaporator coil **72** in the inner loop process air stream. The discharge of the optional evaporator **72** is connected via conduit **83** to the suction port of the compressor **80**.

Method of Operation Cooling and Dehumidification One Closed Loop and Refrigeration System

[0139] The air flow paths have been discussed above and will not be described again in detail to avoid repetition. In the closed loop, the air stream **14** crosses the isolated zone Z1 where the desiccant material has been preconditioned at zone Z3 to have elevated moisture content and lower temperature conditions. The crossing air **14** flows through the isolated rotor zone Z1, which gradually heats the desiccant and in increases moisture content, as described above with reference to FIG. **1**B.

[0140] At the start of the regeneration process the rotor **9** rotates such that desiccant material at isolated zone Z1 is pre-wetted and preconditioned by the process at rotor zone Z3. The pre-conditioned desiccant which was located at isolated zone Z1 is rotated to the regeneration rotor zone Z4 and then to zone Z3 continuously at a controlled speed.

[0141] In the refrigerant compression closed cycle of the refrigeration system, the compressor **80** compresses refrigerant gas to increases its pressure and temperature in an isentropic adiabatic process. The refrigerant is then passed through the condenser coils **62** and **60** where the superheated compressed refrigerant dissipates its heat to the crossing air streams **52** and the refrigerant is condensed into a high-pressure liquid. The condenser coils reject the evaporator heat load, the evaporator superheat, and the heat of compression generated by the compressor. The air stream **53** leaving the condenser coil **62** and the air stream **65** leaving the condenser coil **60** are heated. The refrigerant after dissipating its heat through the condenser coils approaches the metering device **81** where the pressure of the liquid is reduced to a lower evaporator pressure condition. When the liquid is expanded into the evaporator coil **72** through the output orifice of the metering device **81**, the temperature and pressure of the refrigerant liquid is reduced. Although only one evaporator coil and expansion valve is shown in the drawings, it should be understood that more than one coil may be provided and an expansion valve may be installed at each evaporator coil.

[0142] The process intake air **30** crosses the isolated regeneration zone Z4 of the rotor **9** where the crossing interchanges its energy with the preconditioned desiccant and exits the rotor as regenerated exhaust air **56** which interchanges its energy through an adiabatic cooling effect and moisture is dissipated into the crossing air **56**. The pre-conditioning of the desiccant material in zone Z1 also affects the rate and equilibrium of moisture release and heat, as described in full in FIG. **1**B. The regenerated exhaust air stream **56** then enters the refrigerant cooling evaporator coil **72** where part of the moisture in the air stream is removed by the evaporator coil which drains into a drain pan and leaves the evaporator coil in air stream **96** which is colder but still somewhat saturated. The colder somewhat saturated air stream **96** then enters isolated desiccant zone Z**3** of the rotor which adsorbs the moisture content in an adiabatic constant enthalpy reaction, and the dehumidified and adiabatically reheated air leaves zone Z**3** air as the process delivery or supply air **31**.

[0143] As mentioned above, the metering device or expansion valve or valves restrict the high-pressure liquid and creates a reverse refrigerant adiabatic effect, after which, the refrigerant is discharged or suctioned to the evaporator coil or evaporator coils **72** at lower refrigerant temperature and pressure conditions, which enable the evaporator coil(s) to absorb heat from the crossing air that is forced through the coil(s) by the evaporator fan. The air exiting the evaporator coil(s) is discharged as cool air and the refrigerant absorption process changes the refrigerant from liquid-gas to gas, which is then suctioned back to the compressor to complete the closed cycle.

[0144] The outdoor condenser fan circulating the air through the condenser coil **62** can be modulated to concentrate the refrigerant energy and capacity towards the condenser coil **60**. This would augment the heat intensity and capacity upon need. Optionally, the closed loop circulating fan **21** may be modulated to also control the heat capacity caused by the refrigerant heat of the condenser coil **60**. An additional cooling coil may also be provided in the delivery or supply air stream **31**.

[0145] It should be understood, that the refrigeration system may be provided without the optional condenser coils **62** and/or **60** and the evaporator coil **72**, or may utilize any number of coils connected in a series or parallel sequence or combination thereof. It should also be understood that the condenser coils may be combined as one device, and/or valves may be provided to control refrigerant capacity or to change the series sequence of the condenser coils.

Combined Heat and Cool with Two Closed Loops and Refrigeration System

[0146] FIG. **7**A is a diagrammatic view illustrating an arrangement of the desiccant rotor system similar to FIG. **6**A utilizing dual closed loops as described above and in FIGS. **1**B, **1**C and **2**B in combination with a refrigeration system, and wherein the process intake air crosses the desiccant rotor at two different desiccant zones as shown and described previously in FIG. **6**A. The components that are the same as described previously are assigned the same numerals of reference, but will not be described again in detail to avoid repetition. In this arrangement it should be noted that rotation of the desiccant rotor **9** indicated by arrow **8** is shown to be in a clockwise direction.

[0147] Outdoor air **52** in a separate air flow path or bypass system crosses an optional condenser coil **62** and is discharged as discharge air **53**.

[0148] In the first closed loop cycle and process, the closed loop circulating fan **11** conducts a separate isolated air stream in a flow path **13** across a condenser coil **60** which dissipates its refrigerant energy to the crossing air stream, thereby heating the air stream, and the heated air stream **14** crosses the isolated desiccant zone Z**1** of the rotor **9** and returns to the suction side of the circulating fan in a continuous closed loop that provides constant added heat energy to affect the desiccant temperature and vapor conditions.

[0149] In the second closed loop, the zone circulating fan **21** conducts a separate isolated air stream in a flow path **23** across an evaporator coil **70** which cools the air stream, and the cooled air stream **24** crosses the isolated desiccant zone Z**2** of the desiccant rotor **9** and returns to the suction side of the zone circulating fan **21** in a continuous closed loop that provides constant heat energy removal to affect the desiccant temperature and vapor conditions.

[0150] In this arrangement, the process intake air **30**, which may be any pre-conditioned air or outside air, crosses a second condenser coil **110**, leaves the condenser coil in air flow path **51**, flows through the desiccant zone Z**4** of the rotor, leaves the rotor as regenerated exhaust air **56** which crosses an evaporator coil **72**, leaves the evaporator coil in air flow path **96** which then crosses a third condenser coil **115** and leaves the condenser in air flow path **120** and is discharged as process delivery or supply air **31**.

[0151] FIG. **7**B is a diagrammatic view of the piping and refrigeration coils of the refrigeration system of FIG. **7**A in a series refrigeration coil arrangement. In this arrangement, the discharge port of a compressor **80** is connected via conduit **82** to the intake side of the optional condenser coil **62** in the outdoor air flow path or bypass system, and its discharge side is connected via conduit **87** to the intake of the optional refrigerant condenser coil **60** in the first closed loop regeneration air system. The discharge side of the condenser coil **60** is connected via conduit **85** the condenser coil **115** of the process air stream. The discharge side of the condenser coil **115** is connected via conduit **117** to the intake of the condenser coil **110** of the process air stream. The discharge side of the condenser coil **110** is connected via conduit **112** to one port of an expansion valve **81** and the other port of the expansion valve is connected via conduit **86** to the intake of the optional evaporator coil **70** in the second closed loop. The discharge side of the evaporator coil **70** is connected via conduit **89** to the intake of the optional evaporator coil **72** in the process air stream. The discharge of the optional evaporator **72** is connected via conduit **83** to the suction port of the compressor **80**.

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[0152] The air flow paths have been discussed above and will not be described again in detail to avoid repetition. In the closed loop, the air stream **14** crosses the isolated zone Z**1** where the desiccant material has been preconditioned at zone Z**3** to have elevated moisture content and lower temperature conditions. The crossing air **14** flows through the isolated rotor zone Z**1**, which gradually heats the desiccant and in increases moisture content. This energy exchange also results in a cooling effect on the desiccant material caused by the heat sink effect and by the adiabatic cooling effect achieved by releasing some moisture in the crossing air stream.

[0153] At the start of the regeneration process the rotor **9** has rotated such that desiccant material at isolated zone Z**1** is pre-wetted and preconditioned by the process at rotor zone Z**3**. The pre-conditioned desiccant which was located at isolated zone Z**1** is rotated to the regeneration rotor zone Z**4** and then to zone Z**3** continuously at a controlled speed.

[0154] In the refrigerant compression closed cycle of the refrigeration system, the compressor **80** compresses refrigerant gas to increases its pressure and temperature in an isentropic adiabatic process. The refrigerant is then passed through the condenser coils **62**, **60**, **110** and **115** where the superheated compressed refrigerant dissipates its heat to the crossing air streams condensing the refrigerant into a high-pressure liquid. The condenser coils reject the evaporator heat load, the evaporator superheat, and the heat of compression generated by the compressor. The air stream **53** leaving the condenser coil **62** and the air stream **65** leaving the condenser coil **60** are heated. The refrigerant after dissipating its heat through the condenser coils approaches the metering device **81** where the pressure of the liquid is reduced to a lower evaporator pressure condition. When the liquid is expanded into the evaporator coils **70** and **72** through the output orifice of the metering device **81**, the temperature and pressure of the refrigerant liquid is reduced. Although two evaporator coils and one expansion valve is shown in the drawings, it should be understood that more than two coils may be provided and an expansion valve may be installed at each evaporator coil.

[0155] The process intake air **30** crosses optional condenser coil **110** which dissipates its heat into the crossing air stream which leaves the condenser in air stream **51** and enters the isolated regeneration zone Z**4** of the rotor **9** where the crossing air interchanges its energy with the preconditioned desiccant and exits the rotor as regenerated exhaust air **56** which interchanges its energy through an adiabatic cooling effect and moisture is dissipated into the crossing air **56**. The regenerated exhaust air stream **56** then crosses the refrigerant cooling evaporator coil **72** where part of the moisture in the air stream is removed by the evaporator coil which drains into a drain pan and leaves the evaporator coil in air stream **96** which is colder but still somewhat saturated. The colder somewhat saturated air stream **96** then enters isolated desiccant zone Z**3** of the rotor which adsorbs the moisture content in an adiabatic constant enthalpy reaction, and the dehumidified and adiabatically reheated air leaves zone Z**3** in air stream **111** and crosses the condenser coil **115** which reheats the air stream **120**, which is discharged as process delivery or supply air **31**.

[0156] As mentioned above, the metering device or expansion valve or valves restrict the high-pressure liquid and creates a reverse refrigerant adiabatic effect, after which, the refrigerant is discharged or suctioned to the evaporator coil or evaporator coils **70**, **72** at lower refrigerant temperature and pressure conditions, which enable the evaporator coil(s) to absorb heat from the crossing air that is forced through the coil(s) by the evaporator fan. The air exiting the evaporator coil(s) is discharged as cool air and the refrigerant absorption process changes the refrigerant from liquid-gas to gas, which is then suctioned back to the compressor to complete the closed cycle.

[0157] Simultaneously as the processes occur in the desiccant rotor zones Z**4** and Z**3**, the processes described above in the first and second closed loops occur in isolated desiccant zones Z**2** and Z**1**. In these zones, the two separate air streams interchange refrigerant energy through the evaporator coil **70** and condenser coil **60** of the refrigeration system, as described above.

[0158] The desiccant at zone Z**3** has been preconditioned by the process air stream prior to rotation to have a lowered temperature and elevated moisture content. The air **14** leaving the condenser coil **60** flows through the isolated rotor zone Z**1**, which gradually heats the desiccant. This energy exchange also results in a cooling effect caused, in part, by the heat sink effect and also caused by an adiabatic cooling effect, thereby releasing some moisture in the air stream leaving the isolated desiccant zone Z**1**. This air enters the intake of the re-circulating fan **11** and the cooled air **13** is discharged to enter the condenser coil **60**. As previously mentioned the condenser coil **60** dissipates its refrigerant energy to the crossing air stream **13**, thereby heating the air stream **14** leaving the condenser coil. The heated air stream **14** re-enters the isolated desiccant zone Z**1** of the rotor **9** in the closed recirculation loop process described above.

[0159] In the second closed loop, the zone circulating fan **21** conducts a separate isolated air stream in a flow path **23** across an evaporator coil **70** which cools the air stream, and the cooled air stream **24** crosses the isolated desiccant zone Z**2** of the desiccant rotor **9** and returns to the suction side of the zone circulating fan **21** in a continuous closed loop that provides constant heat energy removal to affect the desiccant temperature and vapor conditions. The desiccant in zone Z**2** has been preconditioned from the regeneration air stream at Z**4** prior to rotation to have an elevated temperature and is substantially dry. The cool air **24** leaving the evaporator coil **70** flows through the isolated rotor zone Z **1**, which gradually cools the desiccant material, and the air **22** leaving zone Z**2** returns to the suction side of the zone circulating fan **21** in the continuous closed loop process described above.

[0160] The transferred and added energy caused by the isolated closed loops and refrigeration energy exchanges results in the transport of sensible energy from the isolated zone Z**2** to isolated zone Z**1**. The closed loops also maximize refrigerant energy and accelerate the vapor differential exiting between both zones Z**3** and Z**4**. As the desiccant is rotated from zone Z**1** to zone Z**4**, the reset of temperature and vapor conditions facilitate preparing it for the next regeneration process.

[0161] The heat transfer feature between the zones Z**2** and Z**1** enables the desiccant and moisture conditions to be reduced in total heat capacitance which diminishes the unwanted re-heat effect of the desiccant when the rotor **9** is rotated from zone Z**2** to the process zone Z**3**. The process intake air **30** flows across the optional evaporator coil **72** absorbs energy through the crossing air stream and the leaving air **96** is cooled before entering zone Z**3** as result of the refrigeration evaporating process and facilitates the absorption of moisture as it crosses zone Z**3**. The air stream leaving zone Z**3** and discharged as process delivery or supply air **31** is also diminished in heat due to the heat sink effect from the rotated desiccant zone Z**2**. These heat transfer process augment the total effective cooling. The air **111** leaving zone Z**3** could be re-heated by the second optional condenser coil **115** to re-capture this heat effect, or an additional evaporator may be used to simply cool the leaving delivery or supply air **31**.

[0162] Although the condenser coil **62** is installed to accommodate condensing energy and diminish the crossing air, other devices may be utilized to bypass the refrigerant so as to enable transfer or re-direct refrigerant energy to any of the other condensing coils **60** and/or **110** and/or **115**.

[0163] It should be understood, that the refrigeration system that the refrigeration system may be provided without the optional condenser coils **62** and/or **60** and/or **115** and/or **110** and the evaporator coils **72** and/or **70**, or may utilize any number of condenser and evaporator coils connected in a series or parallel sequence or combination thereof. It should also be understood that the condenser coils may be combined as one device with a physical air separation and evaporator coils may be combined as one device with a physical air separation. It should also be understood that valves may be provided to control air flow volume and/or to control refrigerant capacity or to direct refrigerant toward alternate condenser coils.

Heat and Cool with Two Closed Loops, Refrigeration System, and Process Air Stream Bypass

[0164] FIG. **8** is a diagrammatic view illustrating a modification of FIG. **7**A wherein the process air stream has a bypass air path that bypasses the desiccant zone Z**3** of the desiccant rotor **9**. The air flow paths, the arrangement of the components, and the series refrigeration coil arrangement are the same as described above with reference to FIG. **7**A, and are assigned the same numerals of reference, but will not described again in detail to avoid repetition. The optional condenser coils **115** and **110** described in FIG. **7**A have been removed

[0165] In this modification, the evaporator has two separate coils **72** and **72**B and the intake process air **30**, which may be any preconditioned air or outside air, may be separated into two air flow paths by damper **101**. In a first air stream, a portion of the process intake air **30** enters the isolated regeneration zone Z**4** of the rotor **9** in air stream **51** where the crossing air interchanges its energy with the preconditioned desiccant and exits the rotor as regenerated exhaust air **56** which interchanges its energy through an adiabatic cooling effect and moisture is dissipated into the crossing air **56**. The regenerated exhaust air stream **56** then crosses the refrigerant cooling evaporator coil **72** where part of the moisture in the air stream is removed by the evaporator coil which drains into a drain pan and leaves the evaporator coil in air stream **96** which is colder but still somewhat saturated. The colder somewhat saturated air stream **96** then enters isolated desiccant zone Z**3** of the rotor which adsorbs the moisture content in an adiabatic constant enthalpy reaction, and the dehumidified and adiabatically reheated air leaves zone Z**3** in air stream **111** and discharged as process delivery or supply air **31**.

[0166] In a bypass air stream, a second portion of the process intake air **30** can be directed by the damper **101** across the evaporator coil **72**B which leaves the evaporator coil in bypass air stream **102** and bypasses the isolated desiccant zone Z**3** of the rotor **9** to rejoin the air stream **111** exiting the desiccant zone Z**3** and the mixed air **120** is discharged as process delivery or supply air **31**. The optional bypass air path enables selective control of the refrigeration cooling effect cause by the refrigeration process.

[0167] Outdoor air **50** in a separate air flow path or bypass system crosses an optional condenser coil **61** and is discharged as discharge air **53**, as described in FIG. **7**A.

[0168] The air flow paths of the first and second closed loops and the refrigeration coil arrangement in the closed loops are the same as described above with reference to FIG. **7**A, and are assigned the same numerals of reference, but will not described again in detail to avoid repetition.

[0169] Although some of the systems described herein utilize refrigerant coils, for purposes of example, it should be understood that other equivalent heating and cooling energy exchange systems and devices may be used, such as a heat pump system and water type heat exchangers.

[0170] It should also be understood that the system and processes described herein may also utilize other heat and cooling energy exchange devices to transfer energy into and out of the system, for example, a solar heating closed loop.

[0171] It should also be further understood that portions or parts of the systems depicted in some of the drawings can be combined or mixed with portions or parts of the systems shown in other drawings to provide additional processes.

[0172] Although, for purposes of example, the invention has been described in various preferred forms, as an air conditioning system for dehumidification, humidification, moisture removal, and capture of moisture, it should be understood that the present invention is not limited to performing only that function. The present desiccant rotor system and process may also be utilized to remove unwanted gases such as carbon dioxide, carbon monoxide, hydrogen, and nitrogen, in the manner of a gas separator, gas accumulator, gas filtering apparatus, or water system accumulator.

[0173] While the invention has been disclosed in various preferred forms, the specific embodiments thereof as disclosed and illustrated herein are considered as illustrative only of the principles of the invention and are not to be considered in a limiting sense in interpreting the claims. The claims are intended to include all novel and non-obvious combinations and sub-combinations of the various elements, features, functions, and/or properties disclosed herein.

[0174] Variations in size, materials, shape, form, function and manner of operation, assembly and use, are deemed readily apparent and obvious to one skilled in the art from this disclosure, and all equivalent relationships to those illustrated in the drawings and described in the specification are intended to be encompassed in the following claims defining the present invention. Thus, it shall be understood that while this invention has been described with respect to various specific examples and embodiments, the invention is not limited thereto and that it can be variously practiced within the scope of the following claims.

1. A thermodynamic closed loop desiccant rotor system for conditioning a fluid, comprising:

a desiccant rotor wheel impregnated with a desiccant material and having an isolated preconditioning zone, an isolated regeneration zone, and an isolated process zone;

a process fluid stream;

a regeneration fluid stream;

heating means in fluid communication with said regeneration zone of said desiccant rotor wheel and said regeneration fluid stream for heating said regeneration fluid stream;

a first isolated preconditioning fluid stream that circulates in a first closed loop independent of said process fluid stream and said regeneration fluid stream;

said first closed loop comprising a first energy exchange means for the exchange of thermal energy with said isolated fluid stream, recirculating means connected in fluid communication with said energy exchange means and said isolated preconditioning zone of said desiccant rotor wheel for recirculating said isolated preconditioning fluid stream in a fluid flow path across said first energy exchange means, and across said isolated preconditioning zone in a continuous closed loop, said first energy exchange means operative to raise or lower the temperature and vapor conditions of said preconditioning fluid stream;

said desiccant rotor wheel rotating continuously such that said desiccant material passes sequentially through said isolated preconditioning zone, said isolated regeneration zone, said isolated process zone, and returns to said isolated preconditioning zone; wherein, in a cycle of operation;

said first isolated preconditioning fluid stream after leaving said first energy exchange means passes through said desiccant material at said preconditioning zone to directly precondition the desiccant material and its moisture content such that the desiccant material reacts to achieve an equilibrium state with the crossing preconditioning fluid stream and the crossing preconditioning fluid stream exits said isolated preconditioning zone having different temperature and vapor conditions relative to entering temperature and moisture conditions;

said preconditioned desiccant material enters said isolated regeneration zone and said heated regeneration fluid stream after leaving said heating means passes through said preconditioned desiccant material thereby accelerating the release of moisture and vapor from the desiccant material into the regeneration fluid stream thereby regenerating the desiccant material;

said desiccant material having reduced moisture and vapor content enters said isolated process zone and said process fluid passes through said desiccant material to adsorbs moisture and exits the isolated process zone as the conditioned fluid; and

said desiccant material reenters said isolated preconditioning zone to repeat the cycle.

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