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(54) **RF REGENERATION OF HYDRO-ABSORPTIVE MATERIAL**

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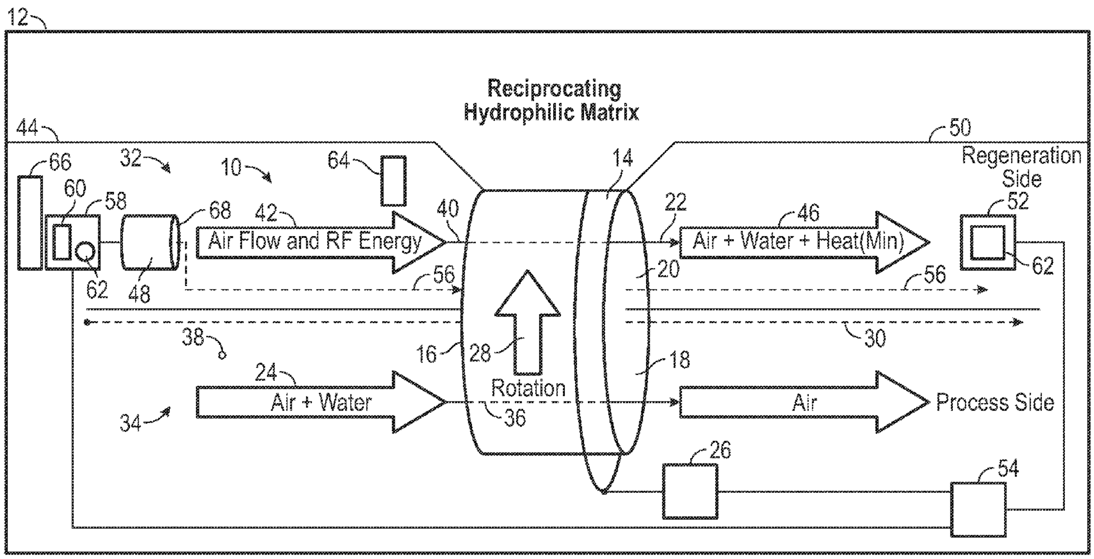
(57) **ABSTRACT**

Disclosed herein is a dehumidifier comprising a regenerable sorption matrix disposed within a drum or wheel in which microwave radiation directed by a waveguide antenna is used to regenerate the sorption matrix within a desorption segment using a programmable controller to coordinate the advancement of the rotation of the sorbent through desorption segment. A method of dehumidifying a process fluid is also disclosed.



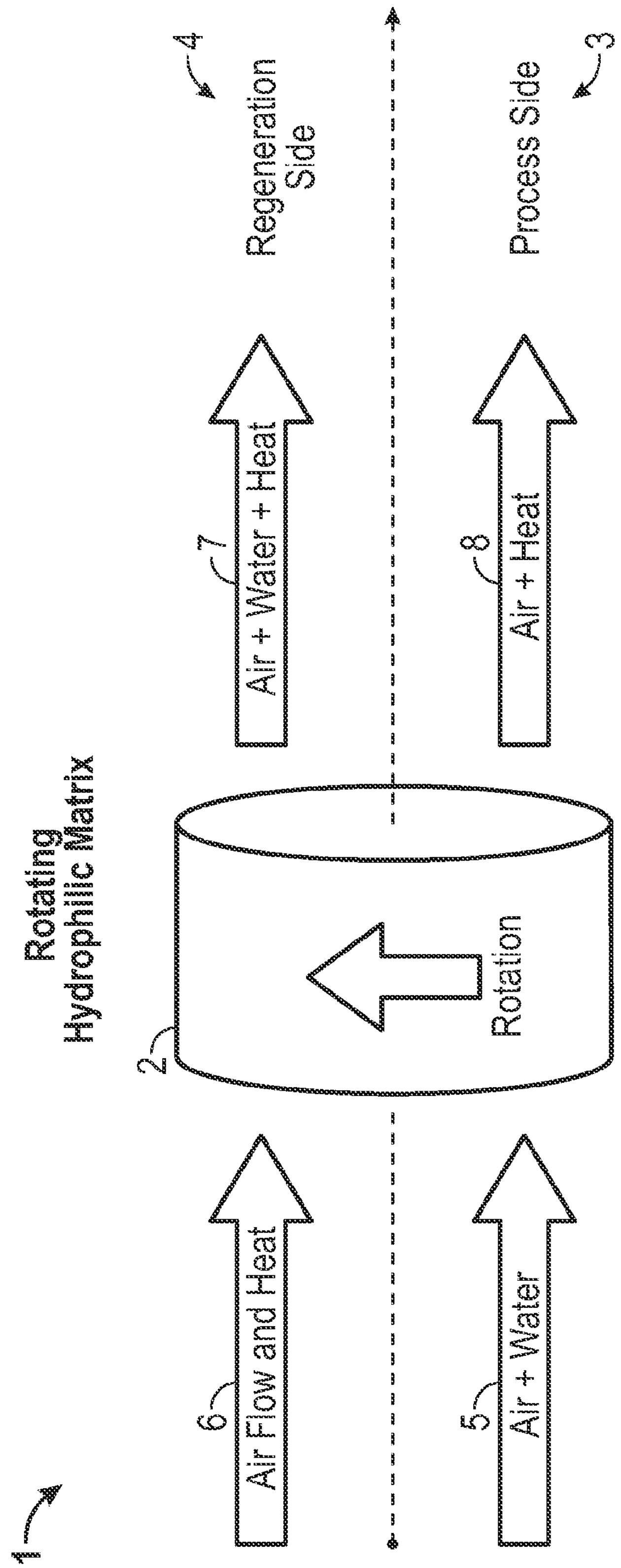
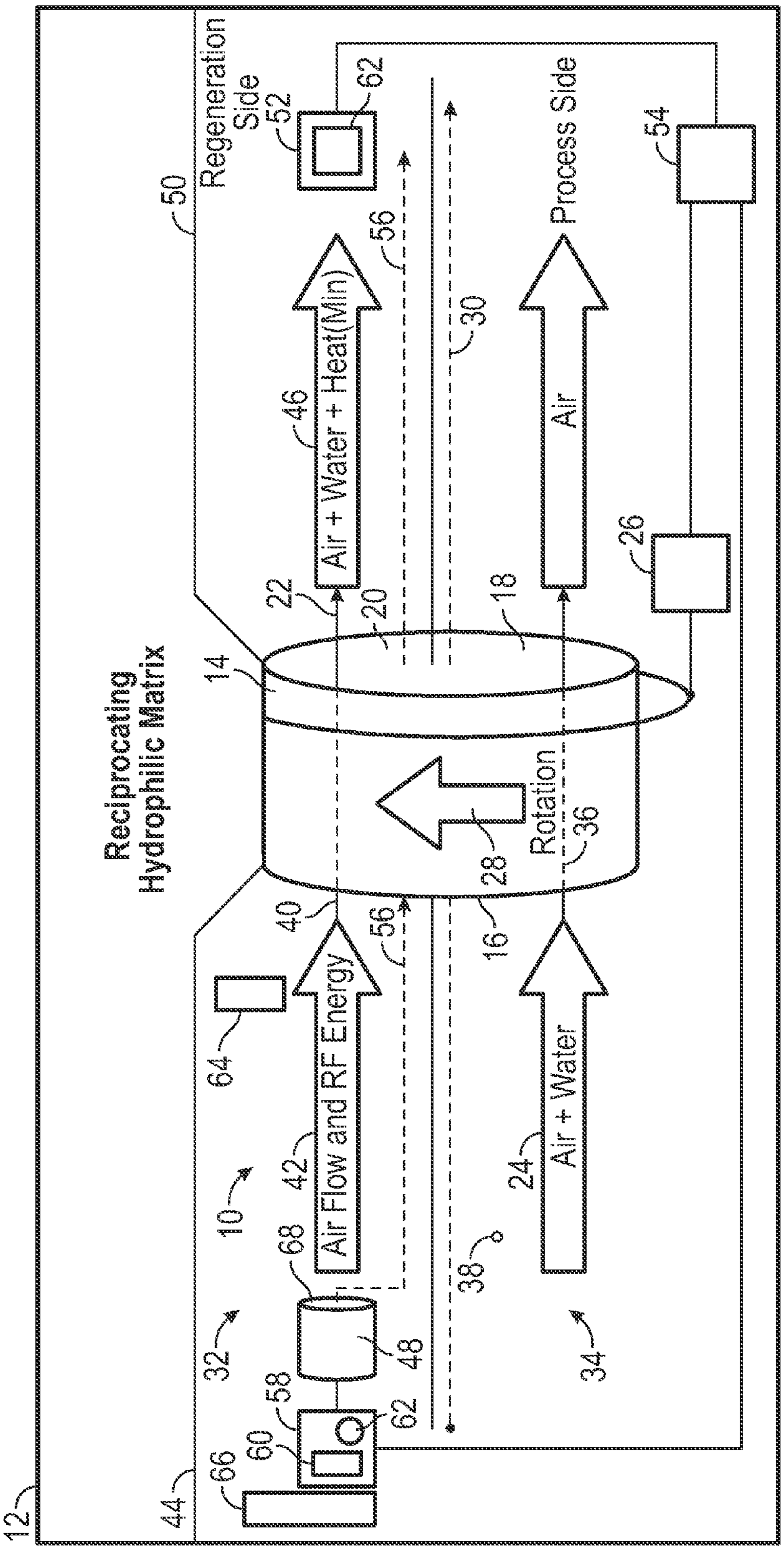


FIG. 1
(Prior Art)



Reciprocating Hydrophilic Matrix
Regeneration Side
Process Side
Air + Water + Heat(Min)
Air
Air Flow and RF Energy
Air + Water
Rotation
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
52
54
56
58
60
62
64
66
68
10

FIG. 2

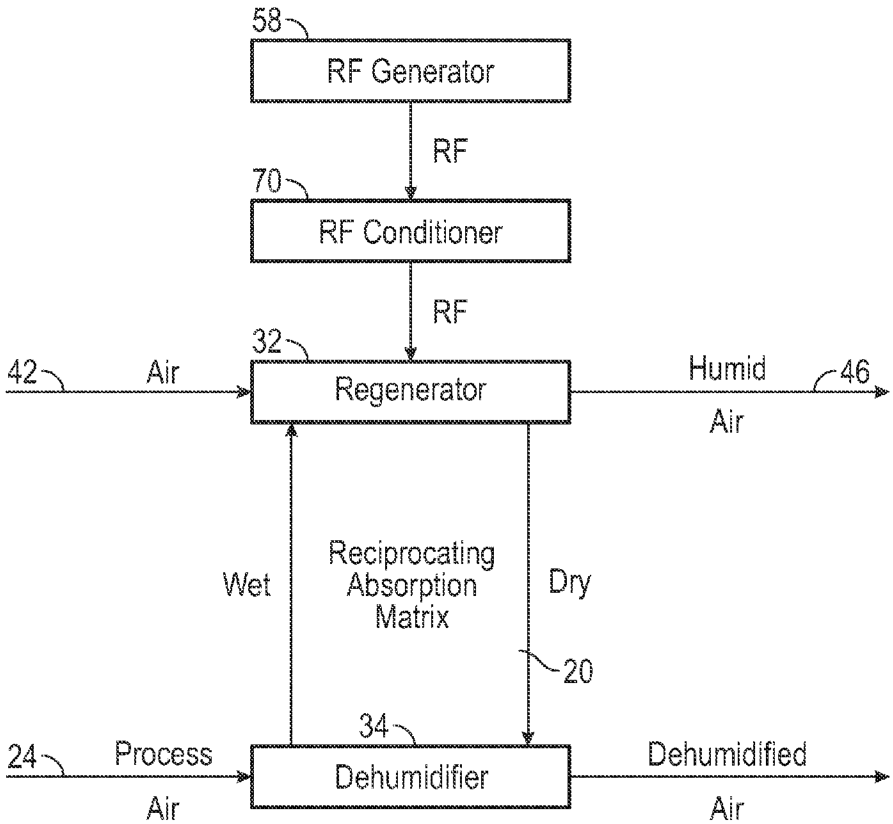

58
RF Generator
RF
70
RF Conditioner
RF
32
42
Air
Regenerator
Humid
Air
46
Wet
Reciprocating
Absorption
Matrix
Dry
20
34
24
Process
Air
Dehumidifier
Dehumidified
Air

FIG. 3

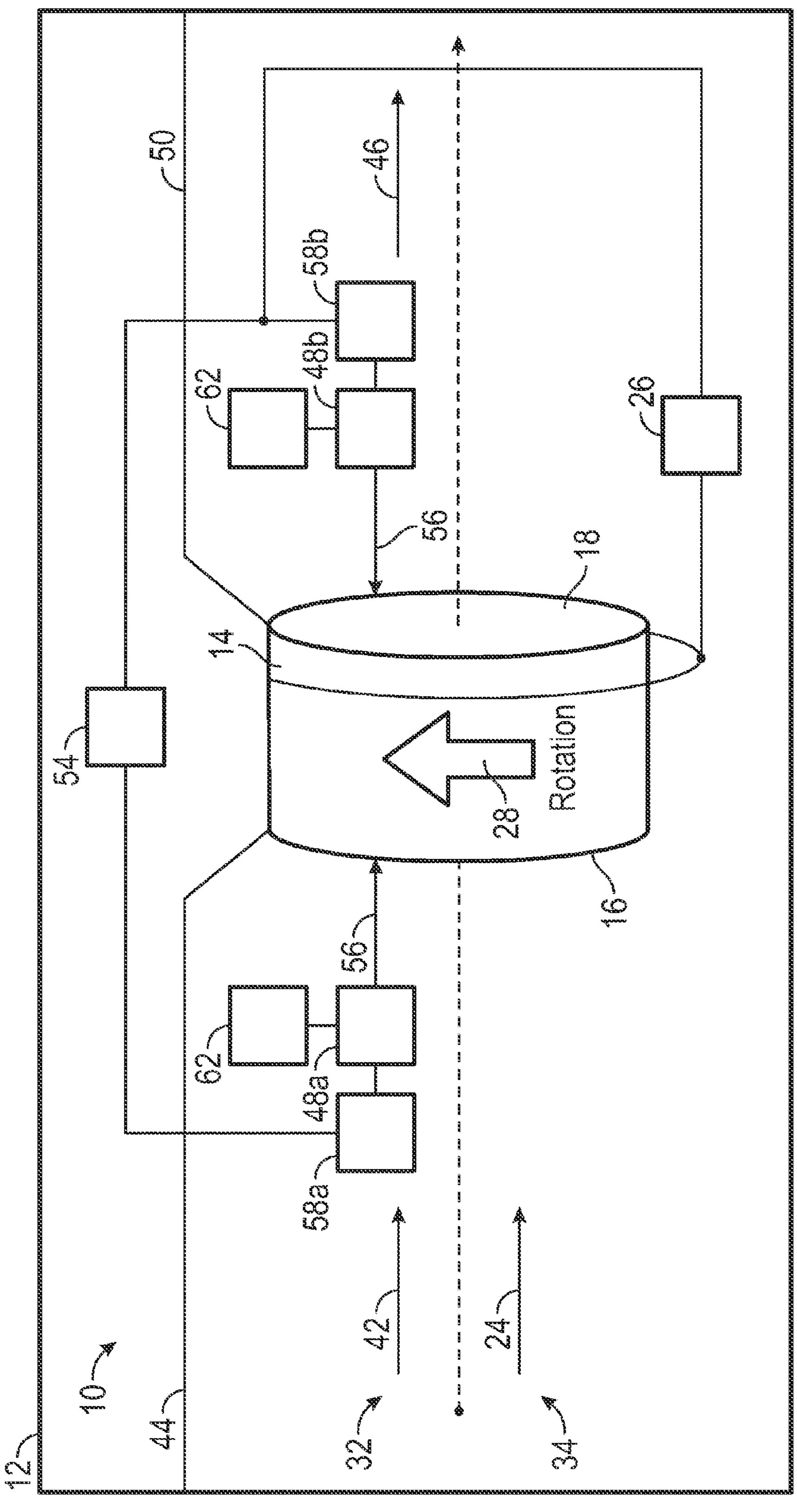

12
10
44
50
32
34
42
24
46
58a
48a
62
56
54
14
16
18
28
Rotation
26
56
48b
62
58b

FIG. 4

RF REGENERATION OF HYDRO-ABSORPTIVE MATERIAL

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] None

BACKGROUND

[0002] The statements in this section merely provide background information related to the present disclosure and may not constitute prior art.

[0003] This invention relates to the regeneration of sorbent, such as a hydroabsorptive materials, such as, for example, in a dehumidifier.

[0004] As shown in FIG. **1**, conventional dehumidifiers **1** operate by rotating a hydrophilic matrix **2** between a process side **3** and a regeneration side **4**. The humid air or other gas to be dehumidified **5** is passed through the process side **3** across the hydrophilic matrix **2** which absorbs moisture from the process fluid, in this case air, to produce dehumidified air **8** which has been warmed by hydrophilic matrix **2**. The hydrophilic matrix **2** is then passed into the regeneration side **4** where it is heated by contact with a stream of hot air **6**, causing secondary ejection of water from the matrix **2** into the regeneration air **7**. Such processes are inefficient in that a relatively large volume of the regeneration air **6** must be heated, considerable energy is lost in the heater, through the walls of the regeneration ducting, and also into the process fluid **8** which is at a higher temperature than the humid air entering the process side **5**. It is generally desired to keep the dehumidified air **8** cool for maximum moisture desorption and process use, e.g., cooling air recirculation in a room or building HVAC system. Moreover, the regeneration side of the apparatus is usually as large as the process side, and conventional dehumidifiers are thus rather large. What is needed is a dehumidification process that is more efficient and/or a dehumidifier that has reduced size requirements.

SUMMARY

[0005] Accordingly, one embodiment disclosed herein is a dehumidifier comprising a rotatable sorption drum having variable portion in communication with one or more microwave sources dimensioned and arranged to direct microwave radiation into the portion of the sorption drum for selective excitation of a sorbate from the portion of the sorption drum.

[0006] In an embodiment a dehumidifier, comprises a regenerable sorption matrix disposed within a drum or wheel in which microwave radiation directed by a waveguide antenna is used to regenerate the sorption matrix within a desorption segment using a programmable controller to coordinate the advancement of the rotation of the sorbent through the desorption segment.

[0007] In an embodiment, a method of dehumidifying a process fluid comprises contacting the process fluid with a sorption matrix disposed within a drum or wheel and then removing the sorbed material (referred to herein as the sorbant) by irradiating a portion of the sorption matrix with microwave radiation directed by a waveguide located in a desorption segment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** shows a block diagram of a prior art dehumidifier;

[0009] FIG. **2** shows a block diagram of an embodiment according to the instant disclosure;

[0010] FIG. **3** shows a block diagram of an embodiment according to the instant disclosure; and

[0011] FIG. **4** shows a block diagram of an alternative embodiment according to the instant disclosure.

DETAILED DESCRIPTION

[0012] At the outset, it should be noted that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developer's specific goals, such as compliance with system related and business related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time consuming but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure. In addition, the composition used/disclosed herein can also comprise some components other than those cited. In the summary and this detailed description, each numerical value should be read once as modified by the term "about" (unless already expressly so modified), and then read again as not so modified unless otherwise indicated in context. As used in the specification and claims, "near" is inclusive of "at."

[0013] The following definitions are provided in order to aid those skilled in the art in understanding the detailed description.

[0014] The terms "sorption" and "sorb" are used herein to include both absorption and adsorption of the sorbate from a fluid. Likewise, the term desorption is the reverse process of absorption, adsorption, or a combination thereof. Accordingly, the sorption matrix functions to absorb, adsorb, or otherwise reversibly sequester a sorbate from a process fluid. The term desorption refers to at least partially releasing the sorbate from the sorbent such that the sorbent may once again function to reversibly remove sorbate from a process fluid.

[0015] For purposes herein, water is used to represent the sorbate and air is utilized to represent the process fluid, and to represent the desorption fluid, consistent with the term dehumidification. However, it is to be understood that the sorbate may be any material dissolved in the process fluid which may be reversibly removed from the process fluid by the sorbent, and the process fluid is not limited to air but may be any material or combination of fluids.

[0016] For purposes herein the Rf source comprises an Rf generator and all of the associated electronics and circuitry coupled to an antenna, which is in communication with, or which is also a waveguide. The waveguide is a structure which guides the microwaves and may comprise a hollow conductive pipe or other hollow structure. Waveguides suitable for use herein may differ in their geometry to confine microwave energy in one dimension or two dimensions. The waveguide may comprise different portions of waveguides as needed to guide the microwave energy to the intended target or substrate. In an embodiment, the waveguide may comprise a rectangular and/or a circular and/or an elliptical cross section.

[0017] In an embodiment, the waveguide may comprise a stripline disposed on a substrate useful to transmit microwave radiation. On or more of the waveguides in communication with the Rf energy providing means may be used to measure various properties of the sorbent drum, the process fluid, the regeneration fluid, or a combination thereof. For purposes herein, the term waveguide and waveguide antenna are used interchangable, unless otherwise noted.

[0018] In an embodiment, the waveguide is a slotted waveguide or slotted antenna which may comprise a metal surface which may include a flat planer portion, with one or more holes or slots, referred to as apertures, disposed through it such that when the metal surface is driven as an antenna by a driving frequency from an Rf source, the slot radiates electromagnetic waves. The shape and size of the slot(s) or appatures, as well as the driving frequency, determine the radiation distribution pattern and provide for greater control of the irradiation pattern of the sorbent drum.

[0019] Other types of antenna which may be suitable for use herein include isotropic radiator antenna, omnidirectional antenna, biconical antenna, directional antenna, and the like. Examples include cage aerial antenna, choke ring antenna, coaxial antenna, crossed field antenna, dielectric resonator antenna, discone antenna, folded unipole antenna, franklin antenna, ground-plane antenna, halo antenna, helical antenna, J-pole antenna, mast radiator antenna, monopole antenna, random wire antenna, rubber ducky antenna, T2FD atenna, T-aerial antenna, umbrella antenna, whip antenna, Adcock antenna, AWX antenna, Beverage antenna, Cantenna antenna, Cassegrain antenna, collinear antenna, conformal antenna, dipole antenna, folded inverted conformal antenna, fractal antenna, Gizmotchy antenna, helical antenna, horizontal curtain antenna, horn antenna, HRS antenna, inverted vee antenna, log-periodic antenna, loop antenna, microstrip antenna, offset dish antenna, patch antenna, phased array antenna, parabolic antenna, plasma antenna, quad antenna, reflective array antenna, regenerative loop antenna, rhombic antenna, sector antenna, short backfire antenna, slot antenna, turnstile antenna, Vivaldi-antenna, WokFi antenna, Yagi-Uda antenna, or a combination thereof.

[0020] Disclosed herein, an embodiment, is a dehumidifier, comprising a sorption chamber having a cylindrical section housing a coaxial sorption drum with first and second end faces at opposite ends thereof; a regenerable sorption matrix comprising sorbent disposed in the sorption drum and comprising axial fluid permeability between the first and second end faces to selectively sorb water from a process fluid; a driver to rotationally advance the sorption drum about a longitudinal axis with respect to a desorption segment; an axial process fluid flow path through the sorption chamber passing through the sorption drum from the first end face to the second end face in fluid isolation from the desorption segment to remove the water from the process fluid; an axial desorption fluid flow path through the desorption segment; a desorption segment supply head fluidly connected against one of the first and second faces of the sorption drum and housing at least one Rf source comprising a waveguide antenna operatively connected with an Rf generator, which in an embodiment may comprise at least one magnetron, to direct microwave radiation into the sorption matrix at a frequency for selective excitation of the sorbate water; a desorption segment receiver head fluidly connected against the other one of the first and second end faces of the sorption drum and housing a receiver comprising an Rf detector, which may include a wide area bolometer to detect microwave radiation passing through the sorption matrix from the antenna; and a programmable controller comprising instructions to coordinate the advancement of the rotation of the sorbent drum with the microwave irradiation of the sorption matrix in response to at least the microwave radiation detected at the receiver.

[0021] As shown in block diagram form in FIG. **2**, in an embodiment, the dehumidifier **10** comprises a sorption chamber **12** having a cylindrical section housing a coaxial sorption drum **14** with first end face **16** and a second end face **18** at opposite ends thereof The sorption drum **14** includes a regenerable sorption matrix **20** comprising sorbent **22** disposed in the sorption drum **14** and comprising axial fluid permeability between the first and second end faces **16** and **18** to selectively sorb a sorbate **38** from a process fluid **24**. In an embodiment, a driver **26** rotationally advances **28** the sorption drum **14** about a longitudinal axis **30** with respect to a desorption segment **32**. In an embodiment, an axial process fluid flow path **36** through the sorption chamber **34** passing through the sorption drum **14** from the first end face **16** to the second end face **18** in fluid isolation from the desorption segment **32** removes the sorbate **38**, which is typically water, from the process fluid **24**. In an embodiment, an axial desorption fluid flow path **40** through the desorption segment **32** enriches the desorption fluid **42** with the sorbate **38** to produce the regenerate fluid stream **46**. In an embodiment, a desorption segment supply head **44** fluidly connected against one of the first and second faces **16** or **18** of the sorption drum **14** houses at least one waveguide antenna **48** to direct microwave radiation **56** into the sorption matrix **20** at a frequency for selective excitation of the sorbate. In an embodiment, a desorption segment receiver head **50** fluidly connected against the other one of the first and second end faces **16** or **18** of the sorption drum **14** houses a receiver **52** to detect microwave radiation **56** passing through the sorption matrix **20** from the antenna **48**. In an embodiment, a programmable controller **54** comprises instructions to coordinate the advancement of the rotation of the sorbent drum **14**, via driver **26**, with the microwave irradiation **56** of the sorption matrix **20** in response to the microwave radiation **56** detected at the receiver **52**.

[0022] In an embodiment, the process fluid **24** comprises air, the sorbate **38** comprises water, and the microwave radiation **56** has a frequency in the range of from 800 MHz to 2.5 GHz. However, microwave radiation frequency is not a limiting factor such that microwave radiation at any frequency suitable to remove a sorbate from the sorbent is suitable for use herein.

[0023] In an embodiment, the antenna comprises a waveguide. In an embodiment, the antenna comprises one or more slotted waveguide antenna **48** operatively connected with an Rf generator **58** comprising at least one magnetron **60** or other source of Rf energy. In an embodiment, the Rf generator **58** comprises a plurality of magnetrons **60**. In an embodiment, the receiver **52** comprises an Rf detector, which may include a wide area bolometer, an Rf diode detector, or diode array detector, or other type of Rf detector **62**.

[0024] In an embodiment, the waveguide antenna **48** comprises one or more microwave lenses **68** to focus or otherwise distribute the microwave radiation **56** to a portion of the sorption drum **14**. In an embodiment, waveguide antenna **48** is dimensioned and arranged such that the sorption matrix is evenly irradiated with the microwave energy based on the cross sectional area of the desorption segment and the area of the sorption matrix being irradiated. In an embodiment, less than 50% of the surface area of one of the two faces of the sorption drum is irradiated with the microwave energy within the desorption segment at any one time, or less than 40% of the surface area, or less than 30% of the surface area, or less than 20% of the surface area, or less than 15% of the surface area, or less than 10% of the surface area, or less than 8% of the surface area, or less than 6% of the surface area, or less than 5% of the surface area, or less than 2% of the surface area is irradiated with the microwave energy within the desorption segment at any one time.

[0025] In an embodiment, the regeneration fluid is not intentionally heated prior to contacting the sorption drum. In an embodiment, the regeneration fluid is not intentionally heated prior to contacting the sorption drum with the exception of utilizing at least a portion of the regeneration fluid to provide cooling for the Rf source, the magnetron, circuitry, drive motors, and/or the like.

[0026] In an embodiment, the Rf generator and the associated waveguide is dimensioned and arranged to provide mixed mode irradiation. In an embodiment, the Rf generator and the associated waveguide is dimensioned and arranged to provide one or more preferential modes of irradiation. In an embodiment, the antenna is a single mode antenna. In an embodiment, the Rf generator is a single source Rf generator. In an embodiment, the Rf generator is a single source Rf generator comprising a waveguide having a plurality of apertures. As shown in FIG. **3**, in an embodiment, the Rf generator **58** may include an Rf conditioner **70** coupled to the antenna **48** disposed within the desorption segment **32**.

[0027] In an embodiment, the Rf generator **58** comprising a tuner **62** to adjust a power level or intensity of the microwave radiation **56** from the antenna **48**. In an embodiment, the desorption segment **32** may include an energy input sensor **64** to measure a level of microwave radiation **56** emitted from the antenna **48**.

[0028] As shown in FIG. **4**, in an embodiment, a plurality of waveguide antenna **48**a and **48**b in communication with one or more Rf generators **58**a and **58**b are arranged to produce a first Rf source dimensioned and arranged to irradiate the first face **16** of the sorption drum **14**, and a second Rf source dimensioned and arranged to irradiate the second face **18** of the sorption drum **14** within the desorption segment. In an embodiment, the first Rf source and the second Rf source also comprise or function as an Rf detector to detect the Rf energy provide by the opposing Rf source. In an embodiment, the first Rf source is operated to irradiate the first face of the sorption drum while the second Rf source is not irradiating the second face of the sorption drum, alternating with the second Rf source being operated to irradiate the second face of the sorption drum while the first Rf source is not irradiating the first face of the sorption drum; both Rf sources are operated to irradiate both faces of the sorption drum simultaneously; or a combination thereof.

[0029] In an embodiment, the sorption matrix **20** comprises a plurality of axial flow passages **36** and **40** through the sorption matrix **20**. In an embodiment, the plurality of axial flow passages **36** and **40** are tortuous. In an embodiment, the sorption matrix **20** comprises a sorbent disposed, fixed, or otherwise attached to one or more surfaces in the axial flow passages.

[0030] In an embodiment, the sorption drum comprises a plurality of latteral flow passages through the sorption matrix and the flow path of the process fluid, the regeneration fluid, and the Rf radiation is from an outer circumference to an inner circumference of the sorption drum. In an embodiment, the plurality of latteral flow passages are tortuous. In an embodiment, the sorption drum comprises a sorption matrix comprising a sorbent disposed, fixed, or otherwise attached to one or more surfaces in the lateral flow passages. In an embodiment, sorption drum **14**, also referred to in the art as a desiccant wheel having axial flow passages, and/or a desiccant drum having lateral flow passages, is a rotatable, air-permeable structure that can absorb and release moisture or another sorbent from a process fluid stream. Sorption drum **14** may comprise a honeycomb structure or porous pad or cage that contains or is coated with a sorbent, e.g., a desiccant, which may comprise silica gel, montmorillonite clay, zeolite, hydrophilic polymers, and/or the like. The actual structure of various sorption drums are well known to those skilled in the art. Examples of suitable sorption drums include those disclosed in U.S. Pat. Nos. 6,311,511; 6,237,354; 5,887,784; 5,816,065; 5,732,562; 5,579,647; 5,551,245; 5,517,828 and 4,719,761, all of which are specifically incorporated by reference herein. In an embodiment, the sorption drum may include one or more pins, plates, grids and/or other structures to direct the microwave radiation, the process fluid, or a combination thereof through the drum.

[0031] In an embodiment, the sorption matrix **20** comprises no transverse fluid permeability, which is defined as fluid permeablility perpendicular to longitudinal axis **30**, or a transverse fluid permeability less than 10% of the axial fluid permeability which is parallel to longitudinal axis **30**.

[0032] In an embodiment, the level of microwave irradiation **56** provided to the sorption drum **14**, and/or the location on the sorption drum **14** where the microwave irradiation is focused, is controlled by programmable controller **54** to maintain the detection of radiation **56** at the receiver **52** at a setpoint or within a range of setpoints.

[0033] In an embodiment, the programmable controller **54** provides instructions comprising holding the sorption drum **14** in rotational position with respect to the desorption segment **32** while the sorption matrix **20** is irradiated. In an embodiment, the programmable controller **54** provides instructions further comprising one or more cycles including the irradiation of the sorption matrix **20** while holding the sorption drum **14** in a position and, when the receiver **52** detects a set level of radiation **56** passing through the sorption matrix **20**, and/or some other detected condition, the programmable controller **54** provides instructions to advance the rotation **28** of the sorption drum **14** to introduce a sorbate-rich portion of the sorption drum **14** into the desorption segment **32**.

[0034] In an embodiment, the controller provides dynamic closed loop control, lookup table control, or a combination thereof with linear control, linear optimization, non-linear control, non-linear optimization, or a combination thereof.

[0035] In an embodiment, the programmable controller **54** provides instructions comprising continuously advancing the rotation **28** of the sorption drum **14** to introduce a sorbate-rich portion of the sorption drum **14** into the desorption segment **32**. In an embodiment, the speed of the the advancement of the rotation **28**, also referred to as the angular velocity of the sorption drum **14**, is controlled to maintain the detection of microwave radiation **56** at the receiver **52** at a setpoint or within a particular range of setpoints consistent with removal of an adequate amount of sorbate under a particular set of conditions.

[0036] In an embodiment, a cross-sectional flow area through the sorption drum in the desorption segment **32** is less than 25%, or less than 20%, or less than 15%, or less than 10% or less than 5% of the cross-sectional flow area available for the process fluid in the sorption chamber **34** through the sorption drum **14**. In an embodiment, a flow direction of the desorption fluid **42** is countercurrent to the direction of the process fluid **24** (not shown). In an embodiment, a process fluid supply for the process fluid **24** to the sorption chamber **34** to enter the sorption drum **14** is located at the first end surface **16**, and the desorption segment supply head **44** is positioned at the second end surface **18** (not shown).

[0037] In an embodiment, desorption segment **32** may further comprise a heater **66** to heat the desorption fluid **42** upstream from the sorption drum **14**. In an embodiment, the Rf generator **58** is in thermal contact with the supply of the desorption fluid **42** such that the Rf generator and associated components are cooled at least in part by the desorption fluid supply, and the desorption fluid supply is at least partially preheated by the Rf generator **58**.

[0038] In an embodiment, the programmable controller **54** provides instructions for passage of the desorption fluid **42** through the sorption matrix **20** without Rf irradiation to cool the sorption drum **14** following the microwave irradiation **56** before the irradiated portion of the sorption drum is returned from the desorption segment **32** to the sorption chamber **34**.

[0039] In an embodiment, the programmable controller **54** may further provide instructions to control an operating parameter relative to a set point or limit, wherein the operating parameter is selected from one or more of instructions to control an operating parameter relative to a detected or measured set point or limit, wherein the operating parameter is selected from one or more of a sorption matrix heating rate, a desorption fluid heating rage, a water removal rate, a sorption matrix temperature, a desorption fluid temperature, a process fluid temperature, a safety condition, a process alarm condition, an equipment alarm condition, a fluid flow rate, a process fluid flow rate, a desorption fluid flow rate, a process fluid humidity level, a desorption fluid humidity level, or a combination thereof.

[0040] In an embodiment, at least a portion of the desorption segment **32** is located within the sorption chamber **34**, while being in fluid isolation therefrom. In an embodiment, the entire desorption segment **32** is located with the sorption chamber **34**.

[0041] In an embodiment, an HVAC system for a ventilated space comprises a dehumidifier comprising the dehumidifier of any one or combination of the embodiments disclosed herein to supply air from the ventilated space to the sorption chamber as the process fluid and to return dehumidified air from the sorption chamber to the ventilated space or to another section of the HVAC system.

[0042] In an embodiment, a method comprises supplying process fluid to a sorption chamber having a cylindrical section housing a coaxial sorption drum with first and second end faces at opposite ends thereof; passing the process fluid axially through a regenerable sorption matrix comprising sorbent disposed in the sorption drum between the first and second end faces to selectively sorb water from the process fluid; rotationally advancing the sorption drum about a longitudinal axis with respect to a desorption segment in fluid isolation with the sorption chamber; directing microwave radiation into the sorption matrix at a frequency for selective excitation of the sorbate water from a waveguide antenna, which may comprise a slotted waveguide, positioned and arranged in a desorption segment supply head fluidly connected against one of the first and second faces of the sorption drum; detecting microwave radiation passing through the sorption matrix from the antenna through the waveguide at a receiver positioned in a desorption segment receiver head fluidly connected against the other one of the first and second end faces of the sorption drum; passing a desorption fluid axially through the desorption segment and a corresponding segment of the sorption drum to enrich the desorption fluid with the sorbate; and coordinating the advancement of the rotation of the sorption drum with the irradiation of the sorption matrix in response to the radiation detected at the receiver.

[0043] In an embodiment, the method comprises continuously advancing the sorption drum by the rotation of the sorption drum to introduce an sorbate-rich portion of the sorption drum into the desorption segment. In an embodiment, the speed of the advancement of the rotation, also referred to as the angular velocity of the sorption drum, is controlled to maintain the detection of radiation at the receiver at a setpoint or within a range of setpoints.

[0044] In an embodiment, the method comprises controlling the rotation of the sorption drum and/or the level of irradiation of the sorption drum to maintain the detection of radiation at the receiver at a setpoint. In an embodiment, the method may further include detecting and controlling the level of radiation emitted from the antenna to maintain the detection of radiation at the receiver at a setpoint or within a range of setpoints.

[0045] In an embodiment, the method may further comprise heating the desorption fluid upstream from the sorption drum. In an embodiment, the method may further comprise passing the desorption fluid through the sorption matrix in the absence of irradiation to cool the sorption drum following the irradiation before the irradiated portion of the sorption matrix is rotated from the desorption segment to the sorption chamber.

[0046] In an embodiment, the method may further include supplying the process fluid to the sorption chamber counter current to the flow of the desorption fluid. In an embodiment, the method may include supplying the process fluid to enter the sorption drum at the first end surface, and positioning the desorption segment supply head at the second end surface.

[0047] In an embodiment, the method may include ventilating a space, comprising supplying air from the ventilated space to the sorption chamber as the process fluid according to any one of the above embodiments, and returning dehumidified air from the absorption chamber directly to the ventilated space, or to at least one other treatment or processing step prior to air being returned to the ventilated space.

[0048] Accordingly, the instant disclosure provides the following embodiments:

[0049] A. A dehumidifier, comprising:

[0050] (a) a sorption chamber having a cylindrical section housing a coaxial sorption drum with first and second end faces at opposite ends thereof;

[0051] (b) a regenerable sorption matrix comprising sorbent disposed in the sorption drum and comprising axial fluid permeability between the first and second end faces to selectively sorb water from a process fluid;

[0052] (c) a driver to rotationally advance the sorption drum about a longitudinal axis with respect to a desorption segment;

[0053] (d) an axial process fluid flow path through the sorption chamber passing through the sorption drum from the first end face to the second end face in fluid isolation from the desorption segment to remove the water from the process fluid;

[0054] (e) an axial desorption fluid flow path through the desorption segment;

[0055] (f) a desorption segment supply head fluidly connected against one of the first and second faces of the sorption drum and housing at least one waveguide antenna operatively connected with an Rf generator comprising at least one magnetron to direct microwave radiation into the sorption matrix at a frequency for selective excitation of the sorbate water;

[0056] (g) a desorption segment receiver head fluidly connected against the other one of the first and second end faces of the sorption drum and housing a receiver comprising an Rf detector to detect microwave radiation passing through the sorption matrix from the antenna; and

[0057] (h) a programmable controller comprising instructions to coordinate the advancement of the rotation of the sorbent drum with the microwave irradiation of the sorption matrix in response to the microwave radiation detected at the receiver.

[0058] B. The dehumidifier according to Embodiment A, wherein the sorption matrix comprises a plurality of tortuous axial flow passages through the sorption matrix, and no transverse fluid permeability or a transverse fluid permeability less than 10% of the axial fluid permeability.

[0059] C. The dehumidifier according to Embodiment A or B, wherein the programmable controller instructions comprise holding the sorption drum in a rotational position with respect to the desorption segment while the sorption matrix is irradiated.

[0060] D. The dehumidifier according to Embodiment A, B, or C, wherein the programmable controller instructions further comprise a cycle including the irradiation of the sorption matrix while holding the sorption drum in the position and, when the receiver detects a set level of radiation passing through the sorption matrix, advancing the rotation of the sorption drum to introduce a sorbate water-rich portion of the sorption drum into the desorption segment.

[0061] E. The dehumidifier according to Embodiment A, B, C, or D, wherein the programmable controller instructions comprise continuously advancing the rotation of the sorption drum to introduce a sorbate water-rich portion of the sorption drum into the desorption segment.

[0062] F. The dehumidifier according to Embodiment A, B, C, D, or E, wherein an angular velocity of the advancement of the rotation of the sorption drum is controlled to maintain the detection of microwave radiation at the receiver at a set point.

[0063] G. The dehumidifier according to Embodiment A, B, C, D, E, or F, wherein the programmable controller instructions provide for passage of the desorption fluid through a portion of the sorption matrix to cool the sorption drum following the microwave irradiation before return of the portion of the sorption matrix to the sorption chamber.

[0064] H. The dehumidifier according to Embodiment A, B, C, D, E, F, or G, the desorption segment supply head further comprising an energy input sensor to measure a level of microwave radiation emitted from the wave guide antenna.

[0065] I. The dehumidifier according to Embodiment A, B, C, D, E, F, G, or H, wherein a cross-sectional flow area through the sorption drum in the desorption segment is less than 25% of the cross-sectional flow area available for the process fluid through the sorption drum.

[0066] J. The dehumidifier according to Embodiment A, B, C, D, E, F, G, H, or I, wherein the programmable controller further comprises instructions to control an operating parameter relative to a set point or limit, wherein the operating parameter is selected from one or more of a sorption matrix heating rate, a desorption fluid heating rage, a water removal rate, a sorption matrix temperature, a desorption fluid temperature, a process fluid temperature, a safety condition, a process alarm condition, an equipment alarm condition, a fluid flow rate, a process fluid flow rate, a desorption fluid rate, a process fluid humidity level, a desorption fluid humidity level, or a combination thereof.

[0067] K. The dehumidifier according to Embodiment A, B, C, D, E, F, G, H, I, or J, wherein at least a portion of the desorption segment is located within the sorption chamber.

[0068] L. The dehumidifier according to Embodiment A, B, C, D, E, F, G, H, I, J, or K, wherein the waveguide antenna comprises one or more microwave lenses.

[0069] M. A method, comprising:

[0070] a. supplying process fluid to a sorption chamber having a cylindrical section housing a coaxial sorption drum with first and second end faces at opposite ends thereof;

[0071] b. passing the process fluid axially through a regenerable sorption matrix comprising sorbent disposed in the sorption drum between the first and second end faces to selectively sorb water from the process fluid;

[0072] c. rotationally advancing the sorption drum about a longitudinal axis with respect to a desorption segment in fluid isolation with the sorption chamber;

[0073] d. directing microwave radiation into the sorption matrix at a frequency for selective excitation of the sorbate water from a waveguide antenna positioned in a desorption segment supply head fluidly connected against one of the first and second faces of the sorption drum;

[0074] e. detecting microwave radiation passing through the sorption matrix from the antenna at a receiver positioned in a desorption segment receiver head fluidly connected against the other one of the first and second end faces of the sorption drum;

[0075] f. passing a desorption fluid axially through the desorption segment and a corresponding segment of the sorption drum to enrich the desorption fluid with the sorbate;

[0076] g. coordinating the advancement of the rotation of the sorption drum with the irradiation of the sorption matrix in response to the radiation detected at the receiver.

[0077] N. The process according to Embodiment M, wherein the process fluid flow is directed counter current to the desorption fluid flow.

[0078] O. The process according to Embodiment M or N, wherein the directing microwave radiation into the sorption matrix, the coordinating the advancement of the rotation of the sorption drum, or a combination thereof comprises a cycle including irradiation of the sorption matrix while holding the sorption drum in a position and, when the receiver detects a set level of radiation passing through the sorption matrix, advancing the rotation of the sorption drum to introduce a sorbate water-rich portion of the sorption drum into the desorption segment.

[0079] P. The process according to Embodiment M, N, or O, wherein the directing microwave radiation into the sorption matrix, the coordinating the advancement of the rotation of the sorption drum, or a combination thereof comprises continuously advancing the rotation of the sorption drum to introduce a sorbate water-rich portion of the sorption drum into the desorption segment.

[0080] Q. The process according to Embodiment M, N, O, or P, wherein an angular velocity of the advancement of the rotation of the sorption drum is controlled to maintain the detection of microwave radiation at the receiver at a set point.

[0081] R. The process according to Embodiment M, N, O, P, or Q, wherein the directing microwave radiation into the sorption matrix, the coordinating the advancement of the rotation of the sorption drum, or a combination thereof includes passage of the desorption fluid through the sorption matrix in the absence of microwave irradiation to cool the segment of the sorption drum following the microwave irradiation before return the segment of the sorption drum from the desorption segment to the sorption chamber.

[0082] S. The process according to Embodiment M, N, O, P, Q, or R, further comprising determining a level of microwave radiation emitted from the wave guide antenna from an energy input sensor and the directing microwave radiation into the sorption matrix, the coordinating the advancement of the rotation of the sorption drum, or a combination thereof is relative to the level of microwave radiation emitted from the antenna in combination with the radiation passing through the sorption matrix.

[0083] T. The process according to Embodiment M, N, O, P, Q, R, or S, wherein the directing microwave radiation into the sorption matrix, the coordinating the advancement of the rotation of the sorption drum, or a combination thereof further comprises controlling an operating parameter relative to a set point or limit, wherein the operating parameter is selected from one or more of a sorption matrix heating rate, a desorption fluid heating rage, a water removal rate, a sorption matrix temperature, a desorption fluid temperature, a process fluid temperature, a safety condition, a process alarm condition, an equipment alarm condition, a fluid flow rate, a process fluid flow rate, a desorption fluid rate, a process fluid humidity level, a desorption fluid humidity level, or a combination thereof.

[0084] U. The process according to Embodiment M, N, O, P, Q, R, S, or T, further comprising preheating the desorption fluid to a temperature below the vaporization level of the sorbate water prior to directing microwave radiation into the sorption matrix, wherein the temperature of the desorption fluid is increased by heat exchange with a source of the microwave radiation, by heat exchange with an external heater, or a combination thereof.

[0085] V. The dehumidifier according to Embodiment A, B, C, D, E, F, G, H, I, J, K or L, or the process according to Embodiment M, N, O, P, Q, R, S, T or U, wherein the waveguide antenna comprises a slotted waveguide antenna.

[0086] The preceding description has been presented with reference to presently preferred embodiments of the invention. Persons skilled in the art and technology to which this invention pertains will appreciate that alterations and changes in the described compositions and methods can be practiced without meaningfully departing from the principle, and scope of this invention. Accordingly, the foregoing description should not be read as pertaining only to the exact embodiments described and shown in the accompanying drawings, but rather should be read as consistent with and as support for the following claims, which are to have their fullest and fairest scope.

[0087] The foregoing disclosure and description is illustrative and explanatory thereof and it can be readily appreciated by those skilled in the art that various changes in the size, shape and materials, as well as in the details of the illustrated construction or combinations of the elements described herein can be made without departing from the spirit of the disclosure.

[0088] While the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character, it being understood that only some embodiments have been shown and described and that all changes and modifications that come within the spirit of the inventions are desired to be protected. It should be understood that while the use of words such as preferable, preferably, preferred, more preferred or exemplary utilized in the description above indicate that the feature so described may be more desirable or characteristic, nonetheless may not be necessary and embodiments lacking the same may be contemplated as within the scope of the invention, the scope being defined by the claims that follow. In reading the claims, it is intended that when words such as "a," "an," "at least one," or "at least one portion" are used there is no intention to limit the claim to only one item unless specifically stated to the contrary in the claim. When the language "at least a portion" and/or "a portion" is used the item can include a portion and/or the entire item unless specifically stated to the contrary.

[0089] Although only a few example embodiments have been described in detail above, those skilled in the art will readily appreciate that many modifications are possible in the example embodiments without materially departing from this invention. Accordingly, all such modifications are intended to be included within the scope of this disclosure as defined in the following claims. In the claims, means-plus-function clauses are intended to cover the structures described herein as performing the recited function and not only structural equivalents, but also equivalent structures. Thus, although a nail and a screw may not be structural equivalents in that a nail employs a cylindrical surface to secure wooden parts together, whereas a screw employs a helical surface, in the environment of fastening wooden parts, a nail and a screw may be equivalent structures. It is the express intention of the applicant not to invoke 35 U.S.C. §112, paragraph 6 for any limitations of any of the claims herein, except for those in which the claim expressly uses the words 'means for' together with an associated function.

What is claimed is:

1. A dehumidifier comprising:

a rotatable sorption drum having variable portion in communication with one or more microwave sources dimensioned and arranged to direct microwave radiation into the portion of the sorption drum for selective excitation of a sorbate from the portion of the sorption drum.

2. The dehumidifier of claim **1**, wherein the microwave source comprises a slotted antenna.

3. The dehumidifier of claim **1**, further comprises a programmable controller comprising instructions to coordinate the rotation of the sorbent drum with the microwave radiation in response to microwave radiation detected by a receiver.

4. A dehumidifier, comprising:
(a) a sorption chamber having a cylindrical section housing a coaxial sorption drum with first and second end faces at opposite ends thereof;
(b) a regenerable sorption matrix comprising sorbent disposed in the sorption drum and comprising axial fluid permeability between the first and second end faces to selectively sorb water from a process fluid;
(c) a driver to rotationally advance the sorption drum about a longitudinal axis with respect to a desorption segment;
(d) an axial process fluid flow path through the sorption chamber passing through the sorption drum from the first end face to the second end face in fluid isolation from the desorption segment to remove the water from the process fluid;
(e) an axial desorption fluid flow path through the desorption segment;
(f) a desorption segment supply head fluidly connected against one of the first and second faces of the sorption drum and housing at least one waveguide antenna operatively connected with an Rf generator comprising at least one magnetron to direct microwave radiation into the sorption matrix at a frequency for selective excitation of the sorbate water;
(g) a desorption segment receiver head fluidly connected against the other one of the first and second end faces of the sorption drum and housing a receiver comprising an Rf detector to detect microwave radiation passing through the sorption matrix from the antenna; and
(h) a programmable controller comprising instructions to coordinate the advancement of the rotation of the sorbent drum with the microwave irradiation of the sorption matrix in response to the microwave radiation detected at the receiver.

5. The dehumidifier of claim 4, wherein the sorption matrix comprises a plurality of tortuous axial flow passages through the sorption matrix, and no transverse fluid permeability or a transverse fluid permeability less than 10% of the axial fluid permeability.

6. The dehumidifier of claim 4, wherein the programmable controller instructions comprise holding the sorption drum in a rotational position with respect to the desorption segment while the sorption matrix is irradiated.

7. The dehumidifier of claim 4, wherein the programmable controller instructions further comprise a cycle including the irradiation of the sorption matrix while holding the sorption drum in the position and, when the receiver detects a set level of radiation passing through the sorption matrix, advancing the rotation of the sorption drum to introduce a sorbate water-rich portion of the sorption drum into the desorption segment.

8. The dehumidifier of claim 4, wherein the programmable controller instructions comprise continuously advancing the rotation of the sorption drum to introduce a sorbate water-rich portion of the sorption drum into the desorption segment.

9. The dehumidifier of claim 4, wherein an angular velocity of the advancement of the rotation of the sorption drum is controlled to maintain the detection of microwave radiation at the receiver at a set point.

10. The dehumidifier of claim 4, wherein the programmable controller instructions provide for passage of the desorption fluid through a portion of the sorption matrix to cool the sorption drum following the microwave irradiation before return of the portion of the sorption matrix to the sorption chamber.

11. The dehumidifier of claim 4, the desorption segment supply head further comprising an energy input sensor to measure a level of microwave radiation emitted from the wave guide antenna.

12. The dehumidifier of claim 4, wherein a cross-sectional flow area through the sorption drum in the desorption segment is less than 25% of the cross-sectional flow area available for the process fluid through the sorption drum.

13. The dehumidifier of claim 4, wherein the programmable controller further comprises instructions to control an operating parameter relative to a set point or limit, wherein the operating parameter is selected from one or more of a sorption matrix heating rate, a desorption fluid heating rage, a water removal rate, a sorption matrix temperature, a desorption fluid temperature, a process fluid temperature, a safety condition, a process alarm condition, an equipment alarm condition, a fluid flow rate, a process fluid flow rate, a desorption fluid rate, a process fluid humidity level, a desorption fluid humidity level, or a combination thereof.

14. The dehumidifier of claim 4, wherein at least a portion of the desorption segment is located within the sorption chamber.

15. The dehumidifier of claim 4, wherein the waveguide antenna comprises one or more slotted waveguides.

16. A method, comprising:
a) supplying process fluid to a sorption chamber having a cylindrical section housing a coaxial sorption drum with first and second end faces at opposite ends thereof;
b) passing the process fluid axially through a regenerable sorption matrix comprising sorbent disposed in the sorption drum between the first and second end faces to selectively sorb water from the process fluid;
c) rotationally advancing the sorption drum about a longitudinal axis with respect to a desorption segment in fluid isolation with the sorption chamber;
d) directing microwave radiation into the sorption matrix at a frequency for selective excitation of the sorbate water from a waveguide antenna positioned in a desorption segment supply head fluidly connected against one of the first and second faces of the sorption drum;
e) detecting microwave radiation passing through the sorption matrix from the antenna at a receiver positioned in a desorption segment receiver head fluidly connected against the other one of the first and second end faces of the sorption drum;
f) passing a desorption fluid axially through the desorption segment and a corresponding segment of the sorption drum to enrich the desorption fluid with the sorbate; and
g) coordinating the advancement of the rotation of the sorption drum with the irradiation of the sorption matrix in response to the radiation detected at the receiver.

17. The process of claim 16, wherein the process fluid flow is directed counter current to the desorption fluid flow.

18. The process of claim 16, wherein the directing microwave radiation into the sorption matrix, the coordinating the advancement of the rotation of the sorption drum, or a combination thereof comprises a cycle including irradiation of the sorption matrix while holding the sorption drum in a position and, when the receiver detects a set level of radiation passing through the sorption matrix, advancing the rotation of the sorption drum to introduce a sorbate water-rich portion of the sorption drum into the desorption segment.

19. The process of claim 16, wherein the directing microwave radiation into the sorption matrix, the coordinating the

advancement of the rotation of the sorption drum, or a combination thereof comprises continuously advancing the rotation of the sorption drum to introduce a sorbate water-rich portion of the sorption drum into the desorption segment.

20. The process of claim **16**, wherein an angular velocity of the advancement of the rotation of the sorption drum is controlled to maintain the detection of microwave radiation at the receiver at a set point.

21. The process of claim **16**, wherein the directing microwave radiation into the sorption matrix, the coordinating the advancement of the rotation of the sorption drum, or a combination thereof includes passage of the desorption fluid through the sorption matrix in the absence of microwave irradiation to cool the segment of the sorption drum following the microwave irradiation before return the segment of the sorption drum from the desorption segment to the sorption chamber.

22. The process of claim **16**, further comprising determining a level of microwave radiation emitted from the wave guide antenna from an energy input sensor and the directing microwave radiation into the sorption matrix, the coordinating the advancement of the rotation of the sorption drum, or a combination thereof is relative to the level of microwave radiation emitted from the antenna in combination with the radiation passing through the sorption matrix.

23. The process of claim **16**, wherein the directing microwave radiation into the sorption matrix, the coordinating the advancement of the rotation of the sorption drum, or a combination thereof further comprises controlling an operating parameter relative to a set point or limit, wherein the operating parameter is selected from one or more of a sorption matrix heating rate, a desorption fluid heating rage, a water removal rate, a sorption matrix temperature, a desorption fluid temperature, a process fluid temperature, a safety condition, a process alarm condition, an equipment alarm condition, a fluid flow rate, a process fluid flow rate, a desorption fluid rate, a process fluid humidity level, a desorption fluid humidity level, or a combination thereof

24. The process of claim **16**, further comprising preheating the desorption fluid to a temperature below the vaporization level of the sorbate water prior to directing microwave radiation into the sorption matrix, wherein the temperature of the desorption fluid is increased by heat exchange with a source of the microwave radiation, by heat exchange with an external heater, or a combination thereof.

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