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(54) Benævnelse: **VANDADSORPTIONSINDRETNING OG FREMGANGSMÅDE TIL ADSORPTION AF VAND FRA EN GAS**

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WO-A1-90/06165
WO-A1-99/66136
WO-A1-2004/009218
WO-A1-2011/062554
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DESCRIPTION

FIELD OF INVENTION

[0001] The present invention relates to a device for adsorbing water from a gas and a method of adsorbing water from gas.

BACKGROUND

[0002] There are many ways of extracting water from air but many of them struggling with efficiency and that they demand a lot of energy.

[0003] US2005/0044862 A1, WO2011/062554 A1 and WO99/66136 all disclose devices for extracting water from air.

SUMMARY OF INVENTION

[0004] The object of the present invention is to provide a device which overcomes the drawbacks of prior art.

[0005] In a first aspect the present invention relates to a water adsorption device comprising:

a housing having a sealable inlet and a sealable outlet;

a container within the housing, wherein the container has an inlet and an outlet and wherein the inlet of the container communicates with the sealable inlet of the housing and the outlet of the container communicates with the sealable outlet of the housing;

a water adsorbing material confined within the container;

whereby a gas flow may be allowed to flow from the sealable inlet of the housing through the container in contact with the water adsorbing material in the container to the sealable outlet of the housing;

a heating device arranged in thermal contact with the water adsorbing material or the container; and

wherein the housing has at least one wall with an inner surface and an outer surface wherein the inner surface is at least partly facing the inlet or the outlet of the container,

wherein the container and the inner surface of the wall have an emissivity value of not more than 0.5, and
wherein the outer surface of the wall has an emissivity value of at least 0.6. In a second aspect the present invention relates to a method of adsorbing water from a gas comprising:

1. a. providing a device according to the first aspect of the invention;
2. b. bringing a gas flow into contact with the water adsorbing material;
3. c. letting the water adsorbing material adsorb moisture or water from the gas;
4. d. sealing the housing;
5. e. heating the water adsorbing material until the space between the container and the inner surface of the housing is saturated with moisture;
6. f. continuing heating of the water adsorbing material;
7. g. collecting condensed water; and
8. h. unsealing of the housing.

[0006] The embodiments presented below are applicable to both aspects of the present invention.

BRIEF DESCRIPTION OF THE FIGURES

[0007]

Figure 1 is a schematic figure of a cross section of the device according to the present invention.

Figure 2 discloses a schematic figure of a cross section of the device according to the present invention.

Figure 3 discloses a schematic figure of a cross section of the device according to the present invention comprising convection disturber.

Figure 4 are a schematic figures of a cross section of the container with water adsorbing material and heating device.

DETAILED DESCRIPTION OF THE INVENTION

[0008] In the present application "water adsorbing material", "water adsorption material" and "hygroscopic material" are used interchangeably.

[0009] The device according to the present invention is designed for water adsorption from a gas, for example from air. The device may be integrated into another device or may be a standalone device.

[0010] Referring now to figure 1. The water adsorption device according to the present invention **10** comprises a housing **20** with a sealable inlet **22** and a sealable outlet **24** and where said inlet and the outlet are both sealable using any suitable means to close and seal said inlet and outlet. The housing comprises a container **26** having an inlet **28** and an outlet **30** which both are in communication with the sealable inlet **22** and the sealable outlet **24** of the housing respectively. The container comprises a water adsorption material **32** which may be any suitable material for example molecular sieves, active carbon, zeolite, silica gel, LiCl, CaCl, $NaNO_3$, wood, sulphates or any suitable material known to a person skilled in the art or combinations thereof. The inlets and the outlets of the housing and the container are arranged so that the gas **33** may flow from the sealable inlet **22** of the housing through inlet **28** of the container so that the gas comes in contact with the water adsorbing material **32.** The gas will then exit the container **26** through the outlet **30** and out through the sealable outlet **24** of the housing **20.** The dotted arrows in figure 1 represent the gas flow. A heating device **34** is arranged in thermal contact with the water adsorbing material **32** and/or the container **26.** A wall **36** of the housing is arranged at least partly facing the inlet and/or the outlet of the container forming a space **37** between the wall **36** and the container **26.** For example the wall may be arranged opposite to the outlet **30** of the container in the direction of the gas flow and/or opposite to the inlet **28** of the container. The wall has an inner and an outer surface **38** and **40** respectively. The container may be in the form of a net, a cage or a perforated surface and may be made of for example a metal or a metal alloys, for example aluminium.

[0011] The heating device may be manoeuvred using electricity, fuel cells, solar energy or in any other suitable way and the heat could be supplied via electricity, microwaves (for example via the microwave oven principle) or via solar energy.

[0012] The heating device may also be connected to a sealing control mechanism to optimize the process of when the sealable inlet and sealable outlet should be opened and closed and when the heating procedure of the water adsorption material should start. Additionally, the housing is preferably constructed in such a way that the gas volume inside a sealed housing remains substantially constant during heating of the water adsorbing material. This may be accomplished by securing or locking the sealing after closing or using a check valve as a sealing. The device may further comprise a pump or a fan in order to increase the flow of gas into the housing and through the container with the water adsorption material. A pump may also reduce the pressure in the housing when it is sealed. The pump may be a complement to the heating device. When the housing is sealed, the pump would reduce the pressure in the sealed housing in order to shift the vapour pressure balance between the gas in the housing and the hygroscopic material/water adsorbing material. The water would then condense and/or be released from the water adsorbing material and can easily be collected. The pressure in the sealed housing may be reduced using a pump or any other suitable means. If the device comprises a heating device as well, the reduction of pressure could be done prior, during or after heating the hygroscopic material.

[0013] The present invention is based on the fact that a water adsorption material confined in a container adsorbs, and to some extent maybe also absorbs, water from the surrounding gas, preferably air, and preferably to the point of saturation. Thus, after having allowed the water adsorption material to adsorb water, the housing is sealed using a lid or any suitable cover and the water adsorption material is then heated. The sealing should be performed in such a way that the gas volume in the sealed container does not expand during heating. The process of releasing the water from the water adsorbing material is driven by the

difference in vapour pressure of the water in the gas and the water adsorbed in the water adsorbing material. The amount of water released from the water adsorption material to the surroundings can be described by:

$$dm/dt = CA\Delta P = CA(P_1(T_1) - P_2(T_2))$$

where C is a material constant, A is the contact surface between the gas the water adsorption material and P is the vapour pressure. When the gas is saturated, i.e. 100 % relative humidity, the vapour pressure of the adsorbed water in the water adsorption material could still be even higher. The higher vapour pressure and the saturation of the gas make the adsorbed water liquefy. The present invention lowers the amount of energy needed since instead of vaporizing the adsorbed water the present invention only requires the energy to break the bonding between the water and the water adsorption material. This is a result of the fact that vaporizing requires both energy to break the bond between the adsorbed water and the water adsorption material and energy to vaporize the water.

[0014] Unlike the prior art the present invention is therefore not dependent on an internal circulation of air or cooling systems to function. The use of non-insulating or heat conductive material in the present invention makes it unnecessary to use a cooling system.

[0015] During the heating of the water adsorption material the water adsorbed on or to the material will vaporize. When the surrounding gas is saturated with moisture additional heating may cause some of the adsorbed water to go from adsorbed to free liquid water. Additionally, by having walls of heat conducting material (or non-insulating material) the vaporized water may condense on the walls, shifting the equilibrium, facilitating more water to be vaporized from the water adsorption material. The walls of the container and/or the housing may be made of but not limited to metals or metal alloys. The walls of the housing are preferably made of a non-transparent material.

[0016] Referring now to figure 2 and 3. During the heating of the water adsorbing material when the inlet and the outlet of the housing are sealed, a heat transfer through convection **42** may occur in the space **37** between the container and the housing due to the temperature difference between the container and the inner surface of the housing, see figure 2, the so called Nusselt effect. In order to limit said convection the space **37,** which may cause a transfer of heat from the container to the housing, a convection disturber **44** may be arranged between the container and the inner surface of the housing or on at least one of the inner surfaces of the housing on each side of the container, see figure 3. The convection disturber **44** may also have an isolating effect, a thermos effect, around the container and the water adsorption material. In figure 3a a convection disturber **44** is arranged on each side of and along the container forming a space **46.** The disturber **44** in figure 3a is perforated wall preferably having the length L and height H so that air heated in the space between the convection disturber and the container is kept within said space. The disturber **44** may also be in the form of protruding walls or parts from at least one of the inner surfaces of the housing, see figure 3b and c. The walls or parts prodtruding from the inner surface/surfaces of the housing may extend out from the inner surface so that convective flow is hindered or at least disturbed but at the same time allows vapour to enter the space **37** and that air and vapour may exit through the sealable outlet of the housing **24.** The convection disturber may be made of any material that exhibits a low emissivity value and a low heat conducting value, for example the disturber **44** may be made of plastic, aluminium, aluminium foil stainless steel or silver.

[0017] The housing may be thermally isolated from the container with the water adsorbing material and heating device so that the housing is not heated during heating of the water adsorbing material.

[0018] The present inventors have found that the heat emitting features of the container material or the surface of the container **26,** the inner surface **38** of the housing and the outer surface **40** of the housing are important in order to make the system efficient. The energy or heat provided to the water adsorption material should preferably not be radiated into the space **37** between the container and the wall of the housing, however any heat or energy adsorbed by the wall of the housing should be radiated out from the outer surface of the housing. Therefore the emissivity values (in the IR spectrum) of the container or the surface of the container, and the inner surface **38** and the outer surface **40** of the housing are important. The container, the convection disturber and the inner surface of the housing should preferably have a low heat conducting value.

[0019] The radiation loss to a cooler surrounding when a blackbody is radiating energy is according to Stefan Boltzmann law

$$P=\varepsilon\sigma A(T^4-T^4_C)$$

where ε is the emissivity value of the blackbody, Stefan's constant, A radiating area, T temperature of radiator and Tc temperature of surrounding.

[0020] In one embodiment the emissivity value of the container or the surface of the container is not more than 0.5, for example 0.45 or less, or 0.30 or less, or 0.20 or less, or 0.10 or less, or 0.05 or less. Examples of ranges may be 0.5-0.01, or 0.30-0.01, or

0.30-0.05, or 0.20-0.01, or 0.20-0.05, or 0.10-0.05.

[0021] In one embodiment the inner surface is not more than 0.5, for example 0.45 or less, or 0.30 or less, or 0.20 or less, or 0.10 or less, or 0.05 or less. Examples of ranges may be 0.5-0.01, or 0.30-0.01, or 0.30-0.05, or 0.20-0.01, or 0.20-0.05, or 0.10-0.05.

[0022] The emissivity value of the container or the surface of the container and the inner surface is 0.5 or less, for example 0.45 or less, or 0.30 or less, or 0.20 or less, or 0.10 or less, or 0.05 or less. Examples of ranges may be 0.5-0.01, or 0.30-0.01, or 0.30-0.05, or 0.20-0.01, or 0.20-0.05, or 0.10-0.05.

[0023] In one embodiment the container and/or the inner surface of the housing is made of steel, stainless steel, aluminium, aluminium foil or silver. In one embodiment the container and/or the inner surface of the housing is polished, i.e. polished so that radiation in the IR spectrum is lowered.

[0024] The emissivity value of the outer surface is at least 0.6, for example 0.65 or more, or 0.70 or more, or 0.80 or more, or 0.90 or more. Example of ranges may be 0.60-0.90, or 0.70-0.90.

[0025] In one embodiment the outer surface may be painted, anodized or coated to obtain an emissivity value of at least 0.70. By painting the outer surface preferably with a pale paint, for example black or pale black the emissivity value may be 0.80 or more, or 0.90 or more.

[0026] In one embodiment the container or the container surface and the inner surface has an emissivity value of 0.20 or less, and the outer surface has an emissivity value of 0.80 or more.

[0027] In one embodiment the housing of the present invention is substantially made of a non-transparent material such as a metal or a metal alloy, for example aluminum. The aluminum may be further treated to improve the emissivity value.

[0028] Referring now to figure 4. In one embodiment the heating device **34** comprises two or more heating elements **35** arranged in direct contact with the water adsorption material **32.** The two or more heating elements **35** may be arranged in any suitable way in the hygroscopic or water adsorbing material. The heating device may have a Y or fork shape, see figure 4a, or a substantially flat rectangular surface, see figure 4b, or may comprise several heating elements, see figure 4c. By having many heating elements or a large surface of heating element the heating will become much more efficient and more evenly distributed. In figure 4d small metal or heat conducting particles **42** are arranged in order to maintain the heat and/or conduct it.

[0029] An advantage of the present invention is that the present invention does not need a surface for the vaporized water to condense on, the water may condense spontaneously in the gas/air, and the water adsorbed on the water adsorbing material may be released without vaporizing first. The releasing of water without vaporizing first saves energy since the energy required to vaporize is not needed. Without being bound by theory it is believed that if the water adsorbing material is heated very fast for example by using high power a non-linear energy value is obtained. For example the heating may be performed using a power of at least 200 W/kg, or 300 W/kg or more, or 350 W/kg or more, or 400 W/kg or more, or 450 W/kg or more, or 500 W/kg or more. For example, by increasing the power from 250 W/kg to 500 W/kg the energy consumption decreased with around 40%.

[0030] The present invention is aimed at extracting water from gas, preferably air, to either produce water or remove the water from the gas. The latter could be used for example, but not limited to, for dehumidification of indoor environments or in air-conditioning devices.

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US20050044862A1 [0003]
- WO2011062554A1 [0003]
- WO9966136A [0003]

Patentkrav

1. Vandadsorptionsindretning, hvilken indretning omfatter:

et hus, der har et forsegleligt indløb og et forsegleligt udløb;

en beholder inde i huset, hvilken beholder har et indløb og et udløb, og hvilket indløb af beholderen kommunikerer med husets forseglelige indløb, og udløbet af beholderen kommunikerer med husets forseglelige udløb;

et vandadsorberende materiale, der er indesluttet inde i beholderen;

hvor en gasstrøm kan tillades at strømme fra husets forseglelige indløb gennem beholderen i kontakt med det vandadsorberende materiale i beholderen til det forseglelige udløb af huset;

en opvarmningsindretning, der er anbragt i termisk kontakt med det vandadsorberende materiale eller beholderen; og

hvor huset har mindst en væg med en indre overflade og en ydre overflade, hvilken indre overflade mindst delvist vender mod indløbet eller udløbet af beholderen,

hvilken beholder og den indre overflade af huset har en emissionsgrad i IR-spektret på ikke mere end 0,5, og

hvilken ydre overflade af huset har en emissionsgrad i IR-spektret på mindst 0,6.

2. Indretningen ifølge krav 1, hvor husets ydre overflade er malet, anodiseret eller overtrukket, hvilket resulterer i en emissionsgrad i IR-spektret på mindst 0,7.

3. Indretningen ifølge krav 2, hvor den ydre overflade er malet sort, hvilket resulterer i en emissionsgrad i IR-spektret på mindst 0,8.

4. Indretning ifølge et hvilket som helst af kravene 1 til 3, hvor beholderen har en emissionsgrad i IR-spektret på ikke mere end 0,3, fortrinsvis ikke mere end 0,1.

5. Indretningen ifølge krav 4, hvor beholderen har en emissionsgrad i IR-spektret i området fra 0,1-0,05.

6. Indretning ifølge et hvilket som helst af kravene 1 til 2, hvor den indre overflade har en emissionsgrad i IR-spektret på ikke mere end 0,3, fortrinsvis ikke mere end 0,1.

7. Indretningen ifølge krav 6, hvor den indre overflade har en emissionsgrad i IR-spektret i området fra 0,1-0,05.

8. Indretning ifølge et hvilket som helst af de foregående krav, hvor huset er i det væsentlige fremstillet af et ikke-transparent materiale, såsom et metal, for eksempel aluminium.

9. Indretning ifølge et hvilket som helst af de foregående krav, hvor opvarmningsindretningen omfatter to eller flere varmeelementer, der er anbragt i direkte kontakt med vandadsorptionsmaterialet.

10. Indretning ifølge et hvilket som helst af de foregående krav, hvor en konvektionsforstyrrende anordning er anbragt i huset mellem beholderen og husets indre overflade eller på mindst en af husets indre overflader på hver side af beholderen.

11. Fremgangsmåde til at adsorbere vand fra en gas, hvilken fremgangsmåde omfatter:

a. at tilvejebringe en indretning ifølge et hvilket som helst af kravene 1 til 10;

b. at bringe en gasstrøm i kontakt med det vandadsorberende materiale;

c. at lade det vandadsorberende materiale adsorbere fugt eller vand fra gassen;

d. at forsegle huset;

e. at opvarme det vandadsorberende materiale, indtil rummet mellem beholderen og den indre overflade af huset er mættet med fugtighed;

f. at fortsætte opvarmning af det vandadsorberende materiale;

g. at opsamle kondensvand og

h. at bryde forseglingen af huset.

12. Fremgangsmåden ifølge krav 11, hvor opvarmningen udføres ved anvendelse af en effekt på mindst 300 W/kg eller 350 W/kg eller derover eller 400 W/kg eller derover eller 450 W/kg eller derover eller 500 W/Kg eller mere.

DRAWINGS

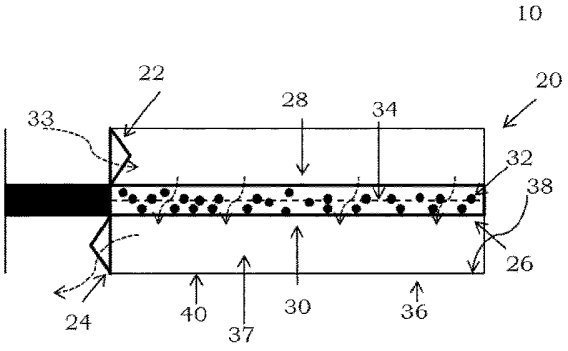

Figure 1

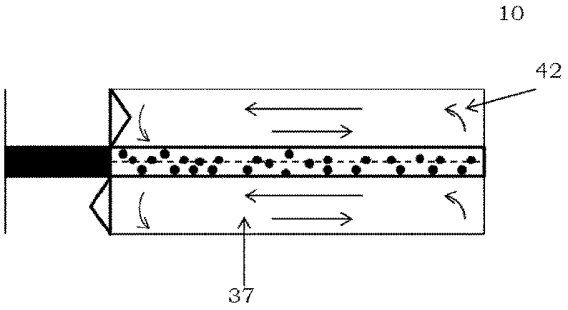

Figure 2.

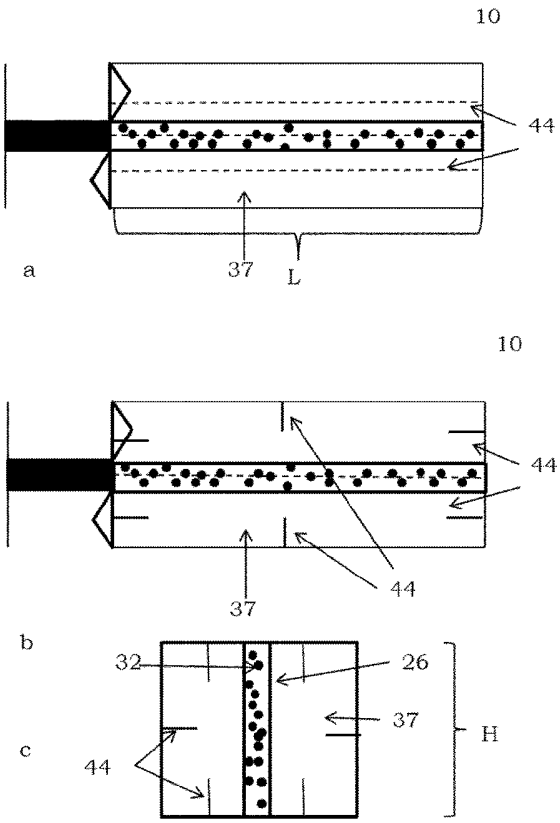

Figure 3

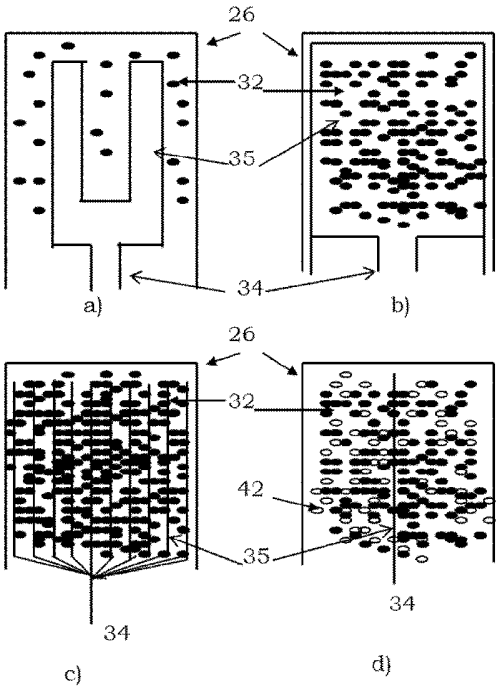

Figure 4.