

[Detailed Descriptions of the Invention]

[Technical Field]

HUMIDITY CONTROL SYSTEM

[0001] This invention relates to humidity control systems for dehumidifying and humidifying air by means of an adsorber.

[Background Art]

[0002] Known humidity control systems for controlling the temperature and humidity of room air include desiccant humidity control systems using the action of moisture adsorption of desiccants.

[0003] For example, a desiccant humidity control system comprises an adsorption element for adsorbing and desorbing moisture in room air and a refrigerant circuit for controlling the temperature of room air. Room air let in the desiccant humidity control system is humidified or dehumidified by the adsorption element and heated or cooled by a heat exchanger in the refrigerant circuit. The adsorption element having adsorbed moisture is thermally regenerated to recover its adsorption capacity.

[0004] The adsorption element of the desiccant humidity control system is composed of a first adsorption element and a second adsorption element. In dehumidifying room air, for example, in summer, the desiccant humidity control system adsorbs moisture in room air on the first adsorption element and, during the time, thermally regenerates the second adsorption element. Then, after a predetermined time has passed, the desiccant humidity control system adsorbs moisture in room air on the second adsorption element and, during the time, thermally regenerates the first adsorption element. In other words, the desiccant humidity control system operates the first and second adsorption elements so that both the elements alternately undergo two behaviors of moisture adsorption and thermal regeneration while changing off with each other (operates in batches). Thus, the desiccant humidity control system continuously controls the humidity of room air without deteriorating dehumidification performance.

[0005] The refrigerant circuit of the desiccant humidity control system essentially

consists of a compressor, a regeneration heat exchanger for regenerating the adsorption element, an expansion mechanism, and a heat exchanger for heating and cooling room air. The compressor, the heat exchangers and the expansion mechanism are connected to each other via piping. The refrigerant circuit operates on a refrigeration cycle by changing the state of refrigerant charged in the piping while the refrigerant circulates in the piping. In the refrigeration cycle, heat of condensation of refrigerant in the regeneration heat exchanger is used, for example, during thermal regeneration of the adsorption element (see Patent Document 1).

[Patent Document 1] Japanese Unexamined Patent Publication No. 2003-97825

[Summary of the Invention]

[Problems to Be Solved by the Invention]

[0006] With the above known humidity control system, however, the refrigeration cycle of the refrigerant circuit may lack the amount of heat for thermal regeneration of the adsorption element. Particularly, if the refrigerant used in the refrigerant circuit is R22 (CHClF_2), which is a refrigerant commonly used in known humidity control systems, a sufficient amount of heat cannot be obtained for thermal regeneration of the adsorption element. As a result, there may arise a problem that the humidity control system deteriorates its humidity control performance.

[0007] The present invention has been made in view of the above points and, therefore, its object is to extensively increase the amount of heat for thermal regeneration of the adsorption element in the refrigerant circuit of the humidity control system to improve the efficiency of regeneration of the adsorption element and thereby enhance the humidity control performance of the humidity control system.

[Means for Solving the Problems]

[0008] The present invention intends to increase the amount of heat for thermal regeneration of an adsorber (80) by providing a large sensible heat zone (R) for refrigerant (106) in a refrigeration cycle.

[0009] Specifically, a first aspect of the invention is directed to a humidity control system which includes an adsorber (80) for controlling the humidity of air to be processed using an adsorbent and a refrigerant circuit (100) for operating on a refrigeration cycle and thermally regenerates the adsorber (80) with heat of refrigerant (106) in the refrigerant circuit (100).

[0010] Further, the humidity control system is characterized by being configured so that the adsorber (80) is formed by adsorption heat exchangers (103, 104) connected to the refrigerant circuit (100) and having an adsorbent carried on their surface; and the sensible heat zone (**R**) for the refrigerant (106) is larger than that for R22 when compared in terms of refrigeration cycles having substantially the same discharge temperature (**B**) of a compressor (101). The discharge temperature (**B**) refers to the temperature of refrigerant discharged from the compressor after undergoing a compression stroke in the compressor.

[0011] In the first aspect of the invention, a refrigerant circuit (100) includes adsorption heat exchangers (103, 104) as adsorbers (80). The humidity of air to be processed is adsorbed by an adsorbent carried on the surface of the adsorption heat exchangers (103, 104). Herein, if the adsorption heat exchangers (103, 104) serve as evaporators in a refrigeration cycle of the refrigerant circuit (100), moisture contained in the air to be processed is adsorbed by the adsorbent. On the contrary, if the adsorption heat exchangers (103, 104) serve as condensers (radiators) in a refrigeration cycle of the refrigerant circuit (100), the adsorption heat exchangers (103, 104) are heated from the inside by the heat of the refrigerant (106), whereby the adsorbent is thermally regenerated.

[0012] Here, the refrigerant (106) used for thermal regeneration of the adsorbent of the adsorption heat exchangers (103, 104) is refrigerant (106) having a larger sensible heat zone (**R**) than R22, which is a commonly known refrigerant, when they are compared in terms of their refrigeration cycles having substantially the same discharge temperature (**B**). The sensible heat zone (**R**) will be described with reference to Figure 10.

[0013] Figure 10 shows a T-S diagram showing a refrigeration cycle using R22 which is

a commonly known refrigerant. The T-S diagram indicates changes of state of R22 in the refrigeration cycle by laying off temperatures of the refrigerant as ordinates and entropies thereof as abscissas. The curve L is the saturation curve (saturation liquid line and saturation vapor line) of R22.

[0014] The refrigerant circuit using R22 operates on a refrigeration cycle shown roughly in the loop $A \rightarrow B \rightarrow C \rightarrow D$. In this refrigeration cycle, thermal regeneration of an adsorbent is implemented out by heat release of R22 in the period from Point B to C. If the temperature required for thermal regeneration of the adsorbent is, for example, 60°C , R22 needs to release heat at a higher temperature than 60°C . Therefore, the sensible heat zone (R) for R22 effective for thermal regeneration of the adsorbent in the period from Point B to C is the hatched area from the level at 60°C to the point at approximately 120°C which is the discharge temperature (B) in the refrigeration cycle. The hatched area indicates the state of refrigerant effectively acting on thermal regeneration of the adsorbent and the area is defined herein as the sensible heat zone (R) cited in "Claims". Since the sensible heat zone (R) shows the area obtained from the refrigerant temperature and entropy, the wider the sensible heat zone (R) is, the larger the amount of heat release for thermal regeneration of the adsorbent becomes.

[0015] In the present invention, the sensible heat zone (R) for the refrigerant (106) is made larger than that for R22, which is a refrigerant commonly used for known humidity control systems, when they are compared in terms of their refrigeration cycles having the same discharge temperature (B). Therefore, the refrigerant (106) in the refrigerant circuit (100) can increase the amount of heat released to thermally regenerate the adsorbent of the adsorption heat exchangers (103, 104). This enhances the efficiency of thermal regeneration of the adsorbent.

[0016] A second aspect of the invention is characterized in that in the humidity control system of the first aspect, the refrigerant circuit (100) is configured so that the pressure of the refrigerant (106) in the high-pressure side of the refrigeration cycle is higher than the

critical pressure of the refrigerant (106).

[0017] In the second aspect, the pressure of the refrigerant (106) in the high-pressure side of the refrigerant circuit (100) during thermal regeneration of the adsorbent of the adsorption heat exchangers (103, 104) is made higher than the critical pressure of the refrigerant (106) to put the refrigerant (106) into a supercritical state. Further, the adsorber (80) is thermally regenerated using a refrigeration cycle in a supercritical state (a supercritical cycle). When the refrigerant (106) is put into a supercritical state, the sensible heat zone (**R**) for the refrigerant (106) is made larger than that for refrigerant in liquid or gas form (in a subcritical state). Therefore, the amount of heat release for thermal regeneration of the adsorbent can be increased.

[0018] A third aspect of the invention is characterized in that in the humidity control system of the first aspect, the refrigerant (106) is a single refrigerant of R32 or a mixed refrigerant containing R32 in the range from 75 weight % inclusive to 100 weight % exclusive.

[0019] In the third aspect, R32 (CH_2F_2)-rich refrigerant having a larger sensible heat zone (**R**) than R22 is used as the refrigerant (106) in the refrigerant circuit (100). Therefore, the amount of heat release for thermal regeneration of the adsorbent of the adsorption heat exchangers (103, 104) can be increased.

[0020] A fourth aspect of the invention is characterized in that in the humidity control system of the second aspect, the refrigerant (106) is CO_2 refrigerant.

[0021] In the fourth aspect, CO_2 having a low critical temperature is used as the refrigerant (106) in the refrigerant circuit (100). Thus, the refrigerant (106) can be easily put into a supercritical state, which increases the sensible heat zone (**R**) for the refrigerant (106). Therefore, the amount of heat release for thermal regeneration of the adsorbent of the adsorption heat exchangers (103, 104) can be increased.

[Effects of the Invention]

[0022] The present invention can provide the following effects.

[0023] In the first aspect of the invention, the refrigerant (106) used for thermal regeneration of the adsorbent carried on the adsorption heat exchangers (103, 104) is refrigerant (106) having a larger sensible heat zone (**R**) than R22 when they are compared in terms of their refrigeration cycles having the same discharge temperature (**B**). Therefore, the amount of heat release of the refrigerant (106) can be increased to improve the efficiency of regeneration of the adsorbent. Therefore, the humidity control performance of the humidity control system can be enhanced.

[0024] In the second aspect of the invention, the pressure of the refrigerant (106) in the high-pressure side of the refrigerant circuit (100) during a refrigeration cycle is made higher than the critical pressure of the refrigerant (106) to put the refrigerant (106) into a supercritical state. Further, the adsorbent of the adsorption heat exchangers (103, 104) is thermally regenerated using a supercritical cycle of the refrigerant (106). When the refrigerant (106) is put into a supercritical state, the sensible heat zone (**R**) for the refrigerant (106) is made larger than that for refrigerant in a subcritical state. Therefore, the amount of heat release for thermal regeneration of the adsorber (80) can be increased thereby improving the efficiency of regeneration of the adsorber (80).

[0025] In the third aspect of the invention, R32-rich refrigerant is used as the refrigerant (106) for thermal regeneration of the adsorbent of the adsorption heat exchangers (103, 104). Since R32 has a larger sensible heat zone (**R**) in a regeneration cycle than R22, the amount of heat release from the refrigerant (106) can be increased thereby improving the efficiency of regeneration of the adsorbent.

[0026] In the fourth aspect of the invention, CO₂ is used as the refrigerant (106) for thermal regeneration of the adsorbent of the adsorption heat exchangers (103, 104) and the refrigerant circuit (100) operates on a supercritical cycle of CO₂. Since CO₂ has a low critical temperature, the refrigerant (106) can be easily put into a supercritical state. Putting CO₂ into a supercritical state increases the sensible heat zone (**R**) for the refrigerant (106). Therefore, the amount of heat release for thermal regeneration of the adsorber (80) can be

increased to further improve the efficiency of regeneration of the adsorber (80). Therefore, the humidity control performance of the humidity control system can be further enhanced.

[Best Mode for Carrying Out the Invention]

[0027] A humidity control system according to an embodiment of the present invention will be described below in detail with reference to the drawings.

[0028] The humidity control system according to this embodiment performs dehumidification and humidification of room air and uses as the adsorber (80) a first adsorption heat exchanger (103) and a second adsorption heat exchanger (104).

[0029] As shown in Figure 1, each of the first adsorption heat exchanger (103) and the second adsorption heat exchanger (104) is formed of a cross-fin-tube type fin-and-tube heat exchanger. Specifically, each of the first adsorption heat exchanger (103) and the second adsorption heat exchanger (104) comprises a large number of aluminium fins (83) each formed in a rectangular plate shape and copper heat transfer pipes (84) passing through the fins (83). An adsorbent, such as zeolite, is carried on the outer surfaces of the fins (83).

[0030] The humidity control system has a flat, hollow, rectangular parallelepiped casing (10). The internal structure of the casing (10) will be described with reference to Figure 2. The bottom of Figure 2B corresponds to the front side of the casing (10) and the top thereof corresponds to the rear side of the casing (10). In the following description, "right", "left", "upper" and "lower" refer to directionalities on the drawings to which the description makes reference.

[0031] The casing (10) is formed in the shape of a flat box generally cubic in plan view. The casing (10) is formed on the right by a first panel (11) and on the left by a second panel (12). A lower part of the first panel (11) is formed toward the front with an intake port (14) and formed toward the rear with an exhaust port (16). On the other hand, an upper part of the second panel (12) is formed toward the front with an indoor suction port (13) and a lower part thereof is formed toward the rear with an outdoor suction port (15).

[0032] The interior of the casing (10) is roughly divided into two spaces one to the right of the other.

[0033] The space of the casing (10) formed toward the first panel (11) is further divided into front and rear spaces by a partition plate (40). Of the front and rear spaces, the rear space forms an exhaust channel (41) and the front space forms an intake channel (42).

[0034] The exhaust channel (41) communicates with the outside of the room through the exhaust port (16). The exhaust channel (41) is provided with an exhaust fan (96) and a compressor (101). On the other hand, the intake channel (42) communicates with the room through the intake port (14). The intake channel (42) is provided with an intake fan (95).

[0035] The space of the casing (10) formed toward the second panel (12) is further divided into three spaces, one in front of another, by a rear partition plate (20) and a front partition plate (30).

[0036] The space behind the rear partition plate (20) is further divided into two spaces one above the other. Out of these two spaces, the upper space forms a rear upper channel (65) and the lower space forms a rear lower channel (66). The rear upper channel (65) communicates with the outdoor suction port (15) but is divided off from the exhaust channel (41). On the other hand, the rear lower channel (66) communicates with the exhaust channel (41) but is divided off from the outdoor suction port (15).

[0037] The space in front of the front partition plate (21) is further divided into two spaces one above the other. Out of these two spaces, the upper space forms a front upper channel (67) and the lower space forms a front lower channel (68). The front upper channel (67) communicates with the indoor suction port (13) but is divided off from the intake channel (42). On the other hand, the front lower channel (68) communicates with the intake channel (42) but is divided off from the indoor suction port (13).

[0038] The space between the rear partition plate (20) and the front partition plate (30) is divided into a first channel (51) and a second channel (52) by a middle partition plate (50).

[0039] The first channel (51) is formed to the left of the middle partition plate (50). The

first adsorption heat exchanger (103) is placed in the first channel (51). The first adsorption heat exchanger (103) divides the first channel (51) into upper and lower spaces. On the other hand, the second channel (52) is formed to the right of the middle partition plate (50). The second adsorption heat exchanger (104) is placed in the second channel (52). The second adsorption heat exchanger (104) divides the second channel (52) into upper and lower spaces.

[0040] As shown in Figure 2A, the rear partition plate (20) is formed with a rear upper left opening (21), a rear upper right opening (22), a rear lower left opening (23), and a rear lower right opening (24). The rear upper left opening (21) is formed in an upper part of the left side of the rear partition plate (20), while the rear upper right opening (22) is formed in an upper part of the right side of the rear partition plate (20). The rear lower left opening (23) is formed in a lower part of the left side of the rear partition plate (20), while the rear lower right opening (24) is formed in a lower part of the right side of the rear partition plate (20).

[0041] The openings (21, 22, 23, 24) of the rear partition plate (20) are provided with open/close dampers, respectively. The dampers for the opening (21, 22, 23, 24) are independently switchable between open and closed positions. When the rear upper left opening (21) is open, the rear upper channel (65) communicates with the upper space of the first channel (51). When the rear upper right opening (22) is open, the rear upper channel (65) communicates with the upper space of the second channel (52). Further, when the rear lower left opening (23) is open, the rear lower channel (66) communicates with the lower space of the first channel (51). When the rear lower right opening (24) is open, the rear lower channel (66) communicates with the lower space of the second channel (52).

[0042] The front partition plate (30) is formed with a front upper left opening (31), a front upper right opening (32), a front lower left opening (33), and a front lower right opening (34). The front upper left opening (31) is formed in an upper part of the left side of the front partition plate (30), while the front upper right opening (32) is formed in an upper

part of the right side of the front partition plate (30). The front lower left opening (33) is formed in a lower part of the left side of the front partition plate (30), while the front lower right opening (34) is formed in a lower part of the right side of the front partition plate (30).

[0043] The openings (31, 32, 33, 34) of the front partition plate (21) are provided with open/close dampers, respectively. The dampers for the opening (31, 32, 33, 34) are independently switchable between open and closed positions. When the front upper left opening (31) is open, the front upper channel (67) communicates with the upper space of the first channel (51). When the front upper right opening (32) is open, the front upper channel (67) communicates with the upper space of the second channel (52). Further, when the front lower left opening (33) is open, the front lower channel (68) communicates with the lower space of the first channel (51). When the front lower right opening (34) is open, the front lower channel (68) communicates with the lower space of the second channel (52).

[0044] – Refrigerant circuit configuration –

Next, the configuration of the refrigerant circuit (100) will be described in detail with reference to the drawings. Figure 3 is a circuit diagram showing the refrigerant circuit (100) of this embodiment.

[0045] The refrigerant circuit (100) is a closed circuit provided with the compressor (101), the first adsorption heat exchanger (103), the second adsorption heat exchanger (104), a four-way selector valve (107), and a motor-operated expansion valve (120). This refrigerant circuit (100) operates on a refrigeration cycle by circulating refrigerant (106) therethrough.

[0046] In the refrigerant circuit (100), the discharge side of the compressor (101) is connected to a first port of the four-way selector valve (107) and the suction side thereof is connected to a second port of the four-way selector valve (107). One end of the first adsorption heat exchanger (103) is connected to a third port of the four-way selector valve

(107), while the other end is connected to one end of the second adsorption heat exchanger (104) through the motor-operated expansion valve (120). The other end of the second adsorption heat exchanger (104) is connected to a fourth port of the four-way selector valve (107).

[0047] The four-way selector valve (107) is configured to freely switch from a position to concurrently allow communication between the first and third ports and communication between the second and fourth ports (the position shown in Figure 3A) to a position to concurrently allow communication between the first and fourth ports and communication between the second and third ports (the position shown in Figure 3B), or vice versa. When the four-way selector valve (107) switches to the first position, the first adsorption heat exchanger (103) acts as a condenser and the second adsorption heat exchanger (104) as an evaporator. On the other hand, when the four-way selector valve (107) switches to the second position, the first adsorption heat exchanger (103) acts as an evaporator and the second adsorption heat exchanger (104) as a condenser.

[0048] Refrigerant having a larger sensible heat zone (R) than R22 is preferably used as the refrigerant (106) in the refrigerant circuit (100) of above configuration. More specifically, refrigerant preferably used as the above refrigerant (106) is a single refrigerant of R32, a mixed refrigerant containing R32 refrigerant in the range from 75 weight % inclusive to 100 weight % exclusive (for example, a mixed refrigerant of R32 and R125), or CO2 refrigerant.

[0049] – Operational behavior –

Next, a description will be made of the operational behavior of the above humidity control system. The humidity control system operates to switch the operation mode from dehumidification to humidification or vice versa. Further, the humidity control system continuously performs dehumidification or humidification while alternately repeating a first behavior and a second behavior by changing the direction of circulation of the refrigerant in the refrigerant circuit (100).

[0050] <Dehumidification mode>

In the first behavior during dehumidification, the refrigerant circuit (100) takes the second position (the position shown in Figure 3B). In this position, the first adsorption heat exchanger (103) acts as an evaporator and the second adsorption heat exchanger (104) acts as a condenser. In the second behavior, the refrigerant circuit (100) takes the first position (the position shown in Figure 3A). In this position, the first adsorption heat exchanger (103) acts as a condenser and the second adsorption heat exchanger (104) acts as an evaporator.

[0051] As shown in Figure 4, when the intake fan (95) is driven in the dehumidification mode, outside air (OA) is taken into the casing (10) through the outdoor suction port (15). The outside air (OA) flows as a first air into the rear upper channel (65). On the other hand, when the exhaust fan (96) is driven, room air (RA) is taken into the casing (10) through the indoor suction port (13). The room air (RA) flows as a second air into the front upper channel (67).

[0052] As shown in Figure 4, in the first behavior during dehumidification, the open/close dampers for the rear upper left opening (21), the rear lower right opening (24), the front upper right opening (32) and the front lower left opening (33) are open but the open/close dampers for the rear upper right opening (22), the rear lower left opening (23), the front upper left opening (31) and the front lower right opening (34) are closed.

[0053] Therefore, the first air let in the rear upper channel (65) flows through the rear upper left opening (21) into the upper space of the first channel (51). Then, the air flows downward, passes through the first adsorption heat exchanger (103) and flows into the lower space of the first channel (51). During the time, moisture in the air is adsorbed on the adsorbent of the first adsorption heat exchanger (103) acting as an evaporator. Heat of adsorption produced during the time is utilized as heat of evaporation for refrigerant in the first adsorption heat exchanger (103).

[0054] The first air thus dehumidified by the first adsorption heat exchanger (103) flows

through the front lower left opening (33) into the front lower channel (68). Thereafter, the air flows through the intake channel (42) and is then supplied through the intake port (14) to the room.

[0055] On the other hand, the second air let in the front upper channel (67) flows through the front upper right opening (32) into the lower space of the second channel (52). Then, the air flows downward, passes through the second adsorption heat exchanger (104) and then flows into the lower space of the second channel (52). During the time, the adsorbent on the second adsorption heat exchanger (104) acting as a condenser is heated so that moisture adsorbed on the adsorbent is desorbed. Thus, the desorbed moisture is given to the air and the adsorbent on the second adsorption heat exchanger (104) is regenerated.

[0056] The second air used for regeneration of the adsorbent on the second adsorption heat exchanger (104) in the above manner flows through the rear lower right opening (66) into the rear lower channel (66). Thereafter, the air flows through the exhaust channel (41) and is then exhausted through the exhaust port (16) to the outside.

[0057] As shown in Figure 5, in the second behavior during dehumidification, the open/close dampers for the rear upper right opening (22), the rear lower left opening (23), the front upper left opening (31) and the front lower right opening (34) are open but the open/close dampers for the rear upper left opening (21), the rear lower right opening (24), the front upper right opening (32) and the front lower left opening (33) are closed.

[0058] Therefore, the first air let in the rear upper channel (65) flows through the rear upper right opening (22) into the upper space of the second channel (52). The air flows downward, passes through the second adsorption heat exchanger (104) and flows into the lower space of the second channel (52). During the time, moisture in the air is adsorbed on the adsorbent of the second adsorption heat exchanger (104) acting as an evaporator. Heat of adsorption produced during the time is utilized as heat of evaporation for refrigerant in the second adsorption heat exchanger (104).

[0059] The first air thus dehumidified by the second adsorption heat exchanger (104)

flows through the front lower right opening (34) into the front lower channel (68). Thereafter, the air flows through the intake channel (42) and is then supplied through the intake port (14) to the room.

[0060] On the other hand, the second air let in the front upper channel (67) flows through the front upper left opening (31) into the upper space of the first channel (51). Then, the air flows downward, passes through the first adsorption heat exchanger (103) and then flows into the lower space of the first channel (51). During the time, the adsorbent on the first adsorption heat exchanger (103) acting as a condenser is heated so that moisture adsorbed on the adsorbent is desorbed. Thus, the desorbed moisture is given to the air and the adsorbent on the first adsorption heat exchanger (103) is regenerated.

[0061] The second air used for regeneration of the adsorbent on the first adsorption heat exchanger (103) in the above manner flows through the rear lower left opening (23) into the rear lower channel (66). Thereafter, the air flows through the exhaust channel (41) and is then exhausted through the exhaust port (16) to the outside.

[0062] <Humidification mode>

In the first behavior during humidification, the refrigerant circuit (100) takes the first position (the position shown in Figure 3A). In this position, the first adsorption heat exchanger (103) acts as a condenser and the second adsorption heat exchanger (104) acts as an evaporator. In the second behavior, the refrigerant circuit (100) takes the second position (the position shown in Figure 3B). In this position, the first adsorption heat exchanger (103) acts as an evaporator and the second adsorption heat exchanger (104) acts as a condenser.

[0063] As shown in Figure 6, when the intake fan (95) is driven in the humidification mode, outside air (OA) is taken into the casing (10) through the outdoor suction port (15). The outside air (OA) flows as a second air into the rear upper channel (65). On the other hand, when the exhaust fan (96) is driven, room air (RA) is taken into the casing (10) through the indoor suction port (13). The room air (RA) flows as a first air into the front

upper channel (67).

[0064] As shown in Figure 6, in the first behavior during humidification, the open/close dampers for the rear upper left opening (21), the rear lower right opening (24), the front upper right opening (32) and the front lower left opening (33) are open but the open/close dampers for the rear upper right opening (22), the rear lower left opening (23), the front upper left opening (31) and the front lower right opening (34) are closed.

[0065] Therefore, the second air let in the rear upper channel (65) flows through the rear upper left opening (21) into the upper space of the first channel (41). Then, the air flows downward, passes through the first adsorption heat exchanger (103) and flows into the lower space of the first channel (41). During the time, the adsorbent of the first adsorption heat exchanger (103) acting as a condenser is heated so that moisture adsorbed on the adsorbent is desorbed. Thus, the desorbed moisture is given to the air.

[0066] The second air thus humidified by the first adsorption heat exchanger (103) flows through the front lower left opening (33) into the front lower channel (68). Thereafter, the air flows through the intake channel (42) and is then supplied through the intake port (14) to the room.

[0067] On the other hand, the first air let in the front upper channel (67) flows through the front upper right opening (32) into the upper space of the second channel (52). Then, the air flows downward, passes through the second adsorption heat exchanger (104) and then flows into the lower space of the second channel (52). During the time, moisture in the air is adsorbed on the adsorbent of the second adsorption heat exchanger (104) acting as an evaporator. Heat of adsorption produced during the time is utilized as heat of evaporation for refrigerant in the second adsorption heat exchanger (104).

[0068] The first air used for regeneration of the adsorbent on the second adsorption heat exchanger (104) in the above manner flows through the rear lower right opening (66) into the rear lower channel (66). Thereafter, the air flows through the exhaust channel (41) and is then exhausted through the exhaust port (16) to the outside.

[0069] As shown in Figure 7, in the second behavior during humidification, the open/close dampers for the rear upper right opening (22), the rear lower left opening (23), the front upper left opening (31) and the front lower right opening (34) are open but the open/close dampers for the rear upper left opening (21), the rear lower right opening (24), the front upper right opening (32) and the front lower left opening (33) are closed.

[0070] Therefore, the second air let in the rear upper channel (65) flows through the rear upper right opening (22) into the upper space of the second channel (52). The air flows downward, passes through the second adsorption heat exchanger (104) and flows into the lower space of the second channel (52). During the time, the adsorbent of the second adsorption heat exchanger (104) acting as a condenser is heated so that moisture adsorbed on the adsorbent is desorbed. Thus, the desorbed moisture is given to the air.

[0071] The second air thus humidified by the second adsorption heat exchanger (104) flows through the front lower right opening (34) into the front lower channel (68). Thereafter, the air flows through the intake channel (42) and is then supplied through the intake port (14) to the room.

[0072] On the other hand, the first air let in the front upper channel (67) flows through the front upper left opening (31) into the upper space of the first channel (51). Then, the air flows downward, passes through the first adsorption heat exchanger (103) and then flows into the lower space of the first channel (51). During the time, moisture in the air is adsorbed on the adsorbent of the first adsorption heat exchanger (103) acting as an evaporator. Heat of adsorption produced during the time is utilized as heat of evaporation for refrigerant in the first adsorption heat exchanger (103). The first air having given moisture to the adsorbent on the first adsorption heat exchanger (103) in the above manner flows through the rear lower left opening (23) into the rear lower channel (66). Thereafter, the air flows through the exhaust channel (41) and is then exhausted through the exhaust port (16) to the outside.

[0073] – Effects of Embodiment –

Next, a description will be made of effects of this embodiment when R32 is used as the refrigerant (106) in the refrigerant circuit (100).

[0074] Figure 8 shows an example of a T-S diagram showing a refrigeration cycle of the refrigerant circuit (100) using R32. The T-S diagram indicates changes of state of R32 in the refrigeration cycle by laying off temperatures of the refrigerant (106) as ordinates and entropies thereof as abscissas. The curve L is the saturation curve of R32.

[0075] The refrigerant circuit (100) using R32 operates on a general refrigeration cycle shown roughly in the loop A→B→C→D. In this refrigeration cycle, A→B indicates the compression stroke in the compressor (101), B→C indicates the condensation stroke in the adsorption heat exchangers (103, 104), C→D indicates the expansion stroke in the motor-operated expansion valve (121, 122), and D→A indicates the evaporation stroke in the adsorption heat exchangers (103, 104). In this refrigeration cycle, thermal regeneration of the adsorbent carried on the adsorption heat exchangers (103, 104) is carried out in the condensation stroke from Point B to C. Next, changes of state of refrigerant (106) from Point B to C will be described.

[0076] At Point B which is the discharge temperature of the compressor (101), R32 compressed into high-temperature, high-pressure superheated vapor reaches approximately 120°C. Next, R32 at Point B exchanges heat with air in the adsorption heat exchangers (103, 104), so that the adsorbent is thermally regenerated, in the period from Point B to C. During the period, R32 gradually decreases its temperature by means of heat release to the air to reach approximately 60°C (B→B₁). Then, R32 gradually condenses from saturated vapor to saturated liquid (B₁→B₂). R32 is further cooled into a supercooled liquid (Point C). Since, in this embodiment, the temperature required for thermal regeneration of the adsorbent of the adsorption heat exchangers (103, 104) is set at approximately 60°C, the sensible heat zone (R) effectively acting on thermal regeneration of the adsorbent falls within the hatched area. The sensible heat zone (R) for R32 is larger than the sensible heat zone (R) for R22 having substantially the same discharge temperature (B) as shown in

Figure 10. Therefore, since this embodiment employs R32 as the refrigerant (106) in the refrigerant circuit (100), it provides a larger sensible heat zone (R) than R22 to increase the amount of heat release to the air from the regeneration heat exchanger (102). This improves the efficiency of thermal regeneration of the adsorbent.

[0077] Such improvement in the efficiency of thermal regeneration due to increase in sensible heat zone (R) can be provided likewise with the use of an R32-rich mixed refrigerant (a mixed refrigerant containing R32 in the range from 75 weight % inclusive to 100 weight % exclusive).

[0078] Next, a description will be made of effects of this embodiment when CO₂ is used as the refrigerant (106) in the refrigerant circuit (100). The pressure of the high-pressure side of the refrigerant circuit (100) during the refrigeration cycle is higher than the critical pressure of CO₂, so that the refrigerant (106) in the refrigerant circuit (106) enters a supercritical cycle.

[0079] Figure 9 shows an example of a T-S diagram showing a refrigeration cycle (supercritical cycle) of the refrigerant circuit (100) using CO₂. The T-S diagram indicates changes of state of CO₂ in the refrigeration cycle by laying off temperatures of the refrigerant (106) as ordinates and entropies thereof as abscissas. The curve L is the saturation curve of CO₂. In this refrigeration cycle, A→B indicates the compression stroke in the compressor (101), B→C indicates the heat release stroke in the adsorption heat exchangers (103, 104), C→D indicates the expansion stroke in the motor-operated expansion valve (121, 122), and D→A indicates the evaporation stroke in the adsorption heat exchangers (103, 104). In this refrigeration cycle, thermal regeneration of the adsorbent carried on the adsorption heat exchangers (103, 104) is carried out in the supercritical heat release stroke from Point B to C. Next, changes of state of refrigerant (106) from Point B to C will be described.

[0080] In this refrigeration cycle, in the period from Point B to C, CO₂ is compressed to a higher pressure than its critical pressure into a supercritical state to reach approximately

120°C (Point B). Next, CO₂ at Point B exchanges heat with air in the adsorption heat exchangers (103, 104), so that the adsorbent is thermally regenerated, in the period from Point B to C. During the period, CO₂ in a supercritical state gradually decreases its temperature by means of heat release to the air. In this case, since CO₂ is in a supercritical state, it decreases the temperature down to approximately 40°C (Point C) while keeping a supercritical state, without being condensed as in the aforementioned R32 shown in Figure 8.

[0081] Since, in this embodiment, the temperature required for thermal regeneration of the adsorbent of the adsorption heat exchangers (103, 104) is set at approximately 60°C, the sensible heat zone (R) effectively acting on thermal regeneration of the adsorbent falls within the hatched area. The sensible heat zone (R) for CO₂ is larger than the sensible heat zone (R) for R22 having substantially the same discharge temperature (B) as shown in Figure 10. Therefore, this embodiment employs CO₂ as the refrigerant (106) in the refrigerant circuit (100) to operate on a supercritical cycle, so that it provides a larger sensible heat zone (R) than R22. This improves the efficiency of thermal regeneration of the adsorbent.

[Brief Description of the Drawings]

[0082] [Fig. 1] Figure 1 is a general perspective view of an adsorption heat exchanger used in a humidity control system according to an embodiment.

[Fig. 2] Figure 2 is a general structural diagram of a humidity control system according to an embodiment.

[Fig. 3] Figure 3 is a circuit diagram of a refrigeration circuit according to an embodiment.

[Fig. 4] Figure 4 is a general structural diagram showing the structure of a humidity control system according to an embodiment and the flow of air in the first operation during dehumidification.

[Fig. 5] Figure 5 is a general structural diagram showing the structure of a

humidity control system according to an embodiment and the flow of air in the second operation during dehumidification.

[Fig. 6] Figure 6 is a general structural diagram showing the structure of a humidity control system according to an embodiment and the flow of air in the first operation during humidification.

[Fig. 7] Figure 7 is a general structural diagram showing the structure of a humidity control system according to an embodiment and the flow of air in the second operation during humidification.

[Fig. 8] Figure 8 is a T-S diagram showing an example of a refrigeration cycle using R32 as refrigerant in the refrigerant circuit.

[Fig. 9] Figure 9 is a T-S diagram showing an example of a refrigeration cycle (a supercritical cycle) using CO₂ as refrigerant in the refrigerant circuit.

[Fig. 10] Figure 10 is a T-S diagram showing an example of a refrigeration cycle using R22 as refrigerant in the refrigerant circuit.

[Description of the Reference Numerals]

[0083]

(80) adsorber

(100) refrigerant circuit

(103) first adsorption heat exchanger

(104) second adsorption heat exchanger

(106) refrigerant

(B) discharge temperature

(R) sensible heat zone

[Claims]

[Claim 1]

A humidity control system which includes an adsorber (80) for controlling the humidity of air to be processed using an adsorbent and a refrigerant circuit (100) for operating on a refrigeration cycle and thermally regenerates the adsorber (80) with heat of refrigerant (106) in the refrigerant circuit (100),

wherein the adsorber (80) is formed by adsorption heat exchangers (103, 104) connected to the refrigerant circuit (100) and having an adsorbent carried on their surfaces, and

the humidity control system is configured so that the sensible heat zone (R) for the refrigerant (106) is larger than that for R22 when compared in terms of refrigeration cycles having substantially the same discharge temperature (B) of a compressor (101).

[Claim 2]

The humidity control system of claim 1, wherein the refrigerant circuit (100) is configured so that the pressure of the high-pressure side during the refrigeration cycle is higher than the critical pressure of the refrigerant (106).

[Claim 3]

The humidity control system of claim 1, wherein the refrigerant (106) is a single refrigerant of R32 or a mixed refrigerant containing R32 in the range from 75 weight % inclusive to 100 weight % exclusive.

[Claim 4]

The humidity control system of claim 2, wherein the refrigerant (106) is CO₂ refrigerant.