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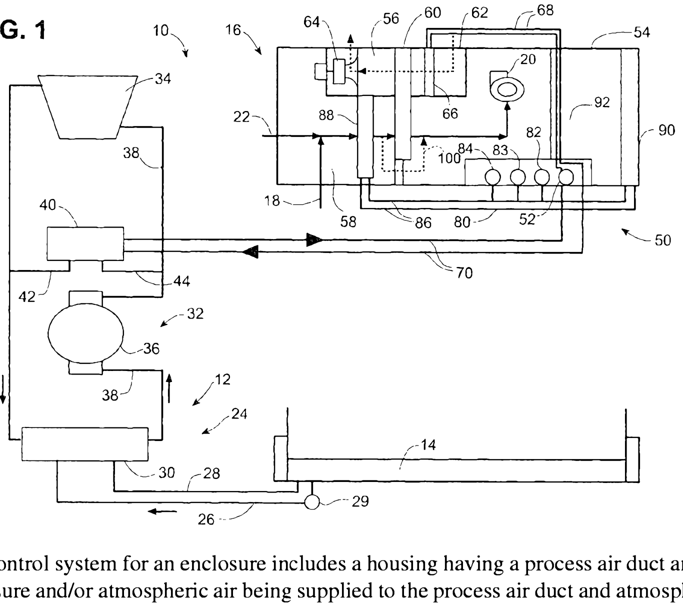
(54) Title: HUMIDITY CONTROL SYSTEM USING A DESICCANT DEVICE

FIG. 1



(57) Abstract: A humidity control system for an enclosure includes a housing having a process air duct and a regeneration air duct, with return air from the enclosure and/or atmospheric air being supplied to the process air duct and atmospheric air being supplied to the regeneration duct. A desiccant wheel is rotatably mounted in the housing for rotation through the ducts for absorbing moisture in the process air duct and releasing moisture in the regeneration duct. A refrigeration system including a condenser coil in the regeneration duct upstream of the desiccant wheel is connected to a heat pump which includes a heat exchanger and a recirculating fluid loop connected between the condenser coil and the heat exchanger for transferring heat from the recirculating fluid loop to said reactivation airstream.

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TITLE

HUMIDITY CONTROL SYSTEM USING A DESICCANT DEVICE

[0001] This application Claims the benefit of U.S. Provisional Application No. 60/924,764 filed May 30, 2007.

Field of the Invention

[0002] The present invention relates to a humidity control system and in particular to a humidity control unit which utilizes low grade waste heat to aid in regeneration of a desiccant device.

BACKGROUND OF THE INVENTION

[0003] Various systems have been proposed for providing air handling systems which maintain humidity levels in indoor facilities in a comfortable range. Certain of these systems have been particularly designed for use in ice arenas in which an ice surface is maintained at freezing temperatures or other applications such as cold storage facilities in which waste heat is available from a large ice plant. Such systems typically use a liquid refrigerant loop which is cooled by a primary refrigerant system of the direct vaporization type. Such systems are shown for example in U.S. Patent No. 6,321,551 in which a dehumidifier unit connected to the ice rink coils is used to dry process air. Another such system is disclosed in U.S. Patent No. 6,935,131 which supplements the dehumidification unit in the process air stream with a reheat coil coupled to a waste heat line from the compressor of the primary refrigeration unit. This reheat coil heats regeneration air being supplied to the regeneration section of a desiccant wheel to increase the desiccant media's capacity to remove further moisture from the process air stream. This reheat coil system is used with a dehumidification coil in the process air section of the dehumidification system which is connected to the liquid refrigeration system.

SUMMARY OF THE INVENTION

[0004] In accordance with an aspect of the present invention a reactivation circuit is provided for preheating regeneration air supplied to a desiccant unit of a dehumidification system. The reactivation circuit consists of a reactivation air cooled condenser coil/dehumidifier coil connected to a direct vaporization refrigeration circuit including a compressor and refrigerant heat exchanger (using water, brine, or other refrigerant) functioning as the evaporator for the circuit. This reactivation circuit functions as a water source heat pump to extract heat from the liquid refrigerant in a secondary refrigeration circuit that freezes the ice sheet. Low grade (low temperature 85-95 degrees F) heat is rejected from the secondary refrigeration plant and extracted by the reactivation circuit to generate a higher grade heat (high temperature 115-130 degrees F) through the air cooled condenser coil to regenerate the desiccant material. The heated air drives moisture from the desiccant and is discharged to the atmosphere.

[0005] In accordance with another aspect of the invention return air, or return air and fresh air, circulated to the interior space or enclosure containing the ice rink or the like is dehumidified in a continuous process by the desiccant material. Preferably the desiccant is a desiccant wheel which rotates through both the supply process air stream and the reactivation air stream. A dehumidification coil is positioned in the reactivation air stream upstream of the regeneration section of the dehumidifier wheel and is connected to a direct vaporization refrigeration circuit having a series of compressors and then to a separate air cooled condenser coil. By this system, if the enclosure humidity level increases, and the return air and/or combination of return air and fresh air humidity is above a predetermined level, the second stage compressor will be energized to cool and dehumidify the air before it reaches the desiccant wheel. Third and fourth stage compressors also are successively energized if the humidity of the air entering the desiccant continues to rise. When the return air humidity is returned to its controlled set point, the compressors stage off in the reverse order and the dehumidifier is eventually de-energized.

[0006] In a more generalized embodiment of the invention the refrigeration circuit which generates the heat for the condensing coil which heats the desiccant regeneration or reactivation air stream is coupled with any low grade liquid heat loop that is decoupled from atmospheric temperature. This means a system which is not bound to atmospheric conditions and allows for control of suitable reactivation temperatures independent of ambient atmospheric temperatures. Accordingly the water, glycol or brine loop need not be limited to the heat rejected from secondary refrigerant loop such as the ice sheet cooling system above, but will include known solar heat loops, cooling tower, ground water loops, other heat of rejection cooling loops, or any loop that is designed to be maintained at a temperature between 45°F and 95°F year round. For example a low grade solar heat loop using water heated by the sun at low temperatures could be used.

[0007] The above and other objects, features and advantages of the present invention will become apparent from the following detailed description of an illustrative embodiment which is to be read in conjunction with the accompanying drawings wherein:

DESCRIPTION OF THE DRAWINGS

[0008] Figure 1 is a schematic diagram of a dehumidifier system in accordance with the present invention; and

[0009] Figure 2 is a more detailed schematic view of one of the refrigeration systems used in the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0010] As seen in Figure 1, the system 10 of the present invention includes a refrigeration system 12 for freezing an ice sheet 14 located within an enclosed space or building (not shown). System 10 further includes a humidity control unit 16 operable to control the humidity of a return air stream 18 coming from the enclosure and being returned thereto by the operation of a fan 20. If required, some proportion of fresh air can be introduced through a duct 22 in known manner into the return air stream.

[0011] The refrigeration system 12 includes a liquid refrigerant secondary refrigeration system 24 which includes a set of coils (not shown) located in the floor of the ice rink or ice plant 14 or the like and connected by supply and return lines 26, 28 and pump 29 to an evaporator 30.

[0012] Evaporator 30 forms a part of a primary refrigeration system 32 which includes a condenser 34 and a compressor 36 connected by lines 38 to a coil within the evaporator 30. The primary refrigeration system is a conventional direct vaporization system which absorbs heat from the liquid refrigeration system in the evaporator and discharges that heat in the condenser 34 to the atmosphere. The primary refrigeration system 32 includes an additional heat exchanger 40 connected by lines 42, 44 to the refrigerant line 38. This heat exchanger functions as an evaporator for a third refrigeration system 50 which is also a direct vaporization refrigeration system. The system 50 includes a compressor 52 located in the housing 54 of the humidity control device 16. That device includes a regeneration air duct 56 and process air duct 58 separated from each other by conventional walls and baffling.

[0013] Dehumidification system 16 also includes a desiccant wheel device 60 of known construction rotatably mounted in the housing such that it is regenerated in the regeneration duct 56 and dehumidifies air in the process air duct 58. The desiccant wheel is of known construction and rotatably mounted in any known manner.

[0014] Regeneration air is drawn into the regeneration duct 56 from the atmosphere through an opening 62 in the housing 54 by a fan 64 which discharges the regeneration air, after it passes through the desiccant wheel, to the atmosphere.

[0015] The refrigeration system 50 includes a condenser coil 66 mounted upstream of the desiccant wheel in the regeneration conduit 56. The coil is connected by refrigerant lines 68 to the compressor 52 which is in turn connected by lines 70 to the heat exchanger 40.

[0016] When it is necessary to dehumidify return air and/or return and fresh air being supplied to the interior of the enclosure, the compressor 52 is operated and supplies cooled refrigerant from the condenser to the heat exchanger 40. The temperature of the coolant in line 70 is raised in the heat exchanger 40 (by the coolant in lines 38 flowing from the line 42 through heat exchanger 40 to line 44) and returned to the compressor 52 where the refrigerant is compressed, heated and supplied to the condenser coil 66. In the condenser coil the refrigerant is cooled by the supply air entering the duct 62 and transfers heat to the regeneration air which then enters the regeneration portion of the rotating desiccant wheel 60 before being charged to the atmosphere. As a result, some of the low grade heat (from the liquid in loop 24, 28 at between 45°F and 95°F) rejected from the ice refrigeration plant or the like is extracted by this heat pump arrangement to generate a higher grade heat (e.g., liquid in line 68 at 105°F to 135°F) through the air cooled condenser coil to regenerate the desiccant wheel. This heated air drives the moisture from the desiccant and regenerates it. It also contributes to cooling of the refrigerant in system 32.

[0017] The above dehumidification process is continuous as the desiccant wheel rotates through the supply and reactivation air streams. However, if the rink humidity level rises above a predetermined point, requiring additional dehumidification, the humidity control device 16 is arranged to provide additional dehumidification, before the return air and/or fresh air/return air pass through the desiccant wheel. As seen most clearly in Figure 2, to accomplish this, the dehumidifier includes an additional refrigeration circuit 80 connected to multiple compressors 82, 83 and 84 which are connected by lines 86 to a dehumidification coil 88 and to an air cooled condenser coil 90 mounted at one end of the housing 54. Thus, when additional dehumidification is required, beyond what the desiccant wheel can provide by itself, the compressor 82 is operated to supply compressed refrigerant to the dehumidification coil which removes moisture from the air before it enters the desiccant wheel device. At the same time it cools the air before it reaches the desiccant wheel. The heat absorbed from the air in the dehumidification coil by the refrigerant is discharged to the atmosphere in the condensation coil 90 which is cooled by the fans 92, and returned to the compressor 82. If still further dehumidification is required, the second and third stage compressors 83 and 84 can be energized.

[0018] As seen more clearly in Figure 2, the refrigeration circuit 80 is actually three independent refrigeration circuits which use different sections of the coils 88, 90 in their individual refrigeration circuits. Thus compressor 82 is connected by lines 82' to coil sections 88' and 90'; compressor 83 is connected by lines 83' to coil sections 88" and 90" and compressor 84 is connected by lines 84' to coil sections 88'" 90'". Each circuit is separately energized as required. and By cooling and dehumidifying the return air before it enters the desiccant wheel in this way the capacity of the desiccant wheel to remove further moisture from the process air stream in increased and the return air is reheated by the wheel to the desired process return temperature.

[0019] If desired or necessary some or all of the process air can be made to bypass the desiccant wheel using appropriate duct work 100 as is known in the art. Also, appropriate temperature and humidity sensors and related controls are provided to selectively activate the various compressors as would occur to those skilled in the art.

[0020] Accordingly, the system provides sufficient capacity to handle varying conditions and variable amounts of make up air without modifying the basic refrigeration systems 12 or 32.

[0021] Although illustrative embodiments of the present invention have been described herein in detail in connection with the accompanying drawings, it is to be understood that the invention is not limited to those precise embodiments but that various changes and modifications may be effected therein by those skilled in the art without departing from the scope or spirit of this invention.

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WHAT IS CLAIMED IS:

1. A humidity control system for an enclosure containing air to be conditioned in the system and a separate additional heating load, a first refrigeration system for cooling the separate additional heating load, and a second refrigeration system for removing heat from the first system, said humidity control system including a housing having a process air duct and a regeneration air duct, means for supplying return air from the enclosure and/or atmosphere air to the process air duct and returning the same to the enclosure; means for supplying atmospheric air to the regeneration duct and then discharging it back to the atmosphere, a desiccant wheel rotatably mounted in said housing for rotation through said ducts whereby the wheel absorbs moisture from the air in the process air duct before it is returned to the enclosure and releases moisture to the air in the regeneration duct before it is discharged to the atmospheric air therein; a third refrigeration system including a condenser coil in said regeneration duct upstream of the desiccant wheel, a compressor connected to said condenser coil, and a heat exchanger connected to said compressor and to said second refrigeration system whereby low grade heat absorbed by the third refrigeration system from said heat exchanger is used by the compressor to generate higher grade heat supplied to the condenser coil to increase the temperature of air supplied to the desiccant wheel in said regeneration duct; and a fourth refrigeration system including a dehumidification coil in said process air stream upstream of said desiccant wheel, at least one compressor connected to said coil and a condenser coil connected to said at least one compressor whereby said at least one compressor in said fourth refrigeration system may be operated in response to humidity levels of the air being supplied in the process air duct to the desiccant wheel to selectively dehumidify such air before it enters the desiccant wheel.

2. A humidity control system as defined in Claim 1 wherein said at least one compressor comprises a plurality of compressors which may be sequentially activated in response to humidity levels of the air being supplied in the process air duct to the desiccant wheel to selectively dehumidify such air before it enters the desiccant wheel.

3. A humidity control system for an enclosure including a housing having a process air duct and a regeneration air duct, means for supplying return air from the enclosure and/or atmospheric air to the process air duct and then returning it to the enclosure; means for

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supplying atmospheric air to the regeneration duct and then discharging it back to the atmosphere, a desiccant wheel rotatably mounted in said housing for rotation through said ducts for absorbing moisture in the air in the process air duct and releasing moisture to the air in the regeneration duct; and a refrigeration system including a condenser coil in said regeneration duct upstream of the desiccant wheel and a heat pump connected to said condenser coil, including a heat exchanger and a recirculating fluid loop connected between said condenser coil and heat exchanger for transferring waste heat from a separate cooling load contained in the recirculating fluid loop to the air in the regeneration duct before entering the desiccant wheel.

4. The system in Claim 3 where said fluid loop is decoupled from atmospheric temperature.

5. The system in Claim 3 where said fluid loop contains a liquid from the group consisting of ground water or glycol loop.

6. The system in Claim 3 where said fluid loop is a cooling tower loop.

7. The system in Claim 3 where said fluid loop is a low grade solar heated loop.

8. The system in Claim 3 where said fluid loop is maintained between 45°F and 95°F year round.

9. The system in Claim 3 where said regeneration air temperature created by the heat pump is between 105°F and 135°F.

10. A humidity control system for an enclosure containing air to be conditioned in the system and a separate additional heating load, a first refrigeration system for cooling the separate additional heating load, and a second refrigeration system for removing heat from the first system, said humidity control system including a housing having a process air duct and a regeneration air duct, means for supplying return air from the enclosure and/or atmosphere air to the process air duct and returning the same to the enclosure; means for supplying atmospheric air to the regeneration duct and then discharging it back to the atmosphere, a desiccant wheel rotatably mounted in said housing for rotation through said

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ducts whereby the wheel absorbs moisture from the air in the process air duct and releases moisture to the air in the regeneration duct; a third refrigeration system including a condenser coil in said regeneration duct upstream of the desiccant wheel, a compressor connected to said condenser coil, and a heat exchanger connected to said compressor and to said second refrigeration system whereby low grade heat absorbed by the third refrigeration system from said heat exchanger is used by the compressor to generate higher grade heat supplied to the condenser coil to increase the temperature of air supplied to the desiccant wheel in said regeneration duct before it enters the desiccant wheel.

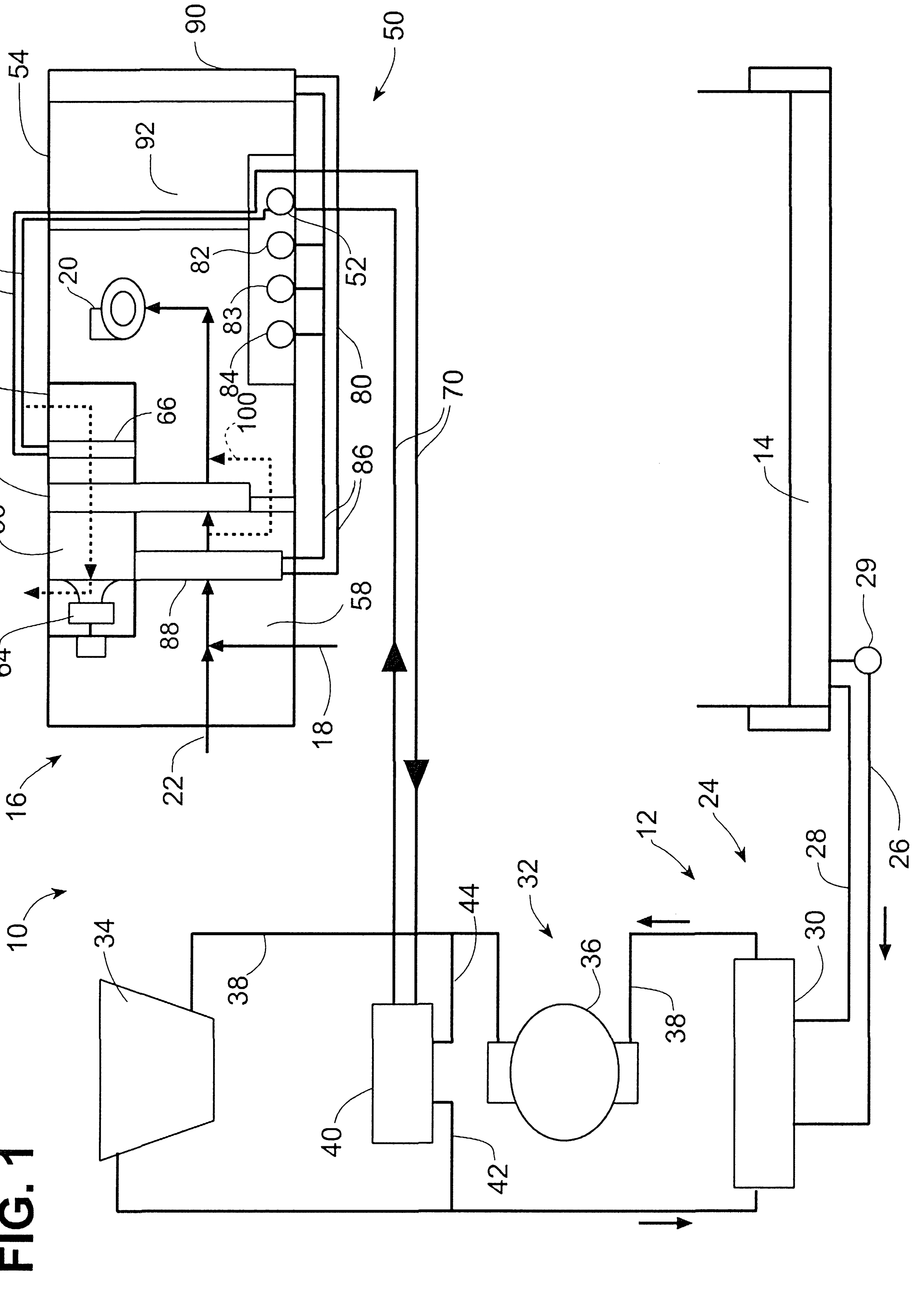
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FIG. 1

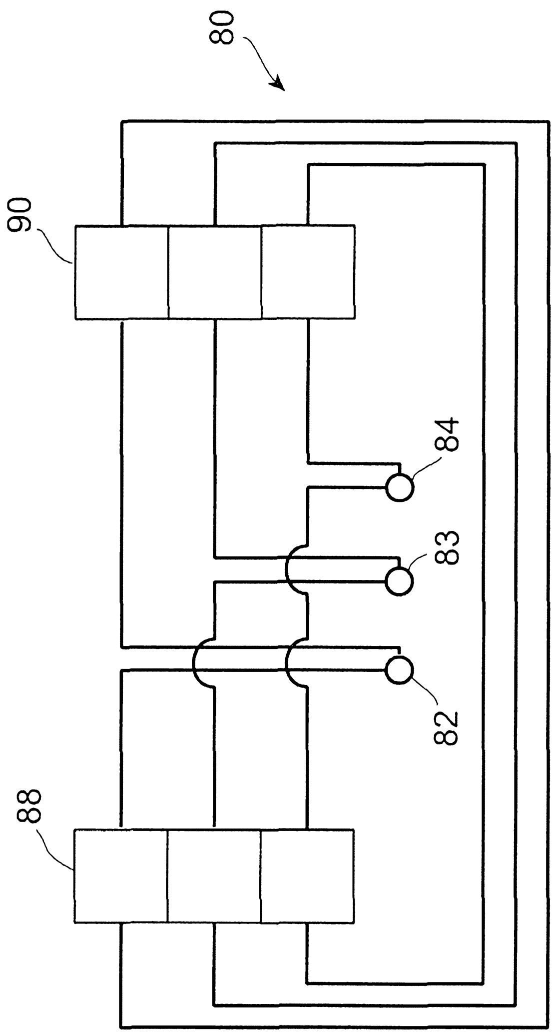

FIG. 2