Title: A METHOD AND SYSTEM FOR CONTROLLING A TEMPERATURE IN AN ABSORPTION CHILLER

Abstract: A method and system for controlling a temperature of a hot water source capable of being used for heating in an absorption chiller includes a first valve for controlling an amount of liquid refrigerant exiting a low stage generator in the absorption chiller, in order to control a pressure in a high stage generator configured for producing steam. A second valve controls an amount of liquid refrigerant exiting a heat exchanger in the absorption chiller, in order to control a heating capacity of the heat exchanger. A controller controls operation of the first and second valves as a function of a temperature of at least one of the hot water source, the liquid refrigerant and an absorbent solution.
A METHOD AND SYSTEM FOR CONTROLLING A TEMPERATURE IN AN ABSORPTION CHILLER

BACKGROUND

[0001] The present disclosure relates to an absorption chiller system. More particularly, the present disclosure relates to a method and system for controlling an outlet temperature of a hot water source capable of being used for heating in a simultaneous heating and cooling absorption chiller.

[0002] A simultaneous heating and cooling absorption chiller may be configured for providing heating and cooling to a building using, respectively, a hot water source and a chilled water source. The absorption chiller may include a heat exchanger configured for receiving the hot water and thereby increasing a temperature of the hot water to a set point temperature. The heat exchanger utilizes steam produced by a generator of the absorption chiller to transfer heat to the hot water source passing through the heat exchanger.

[0003] An outside ambient air temperature may affect operating conditions inside the absorption chiller. More specifically, a low ambient air temperature may reduce pressure inside the generator, which impacts a temperature of the steam produced by the generator. In some cases, a low ambient air temperature may impact an ability of the heat exchanger to increase the hot water temperature to the set point temperature.

[0004] There is a need for a system and method of operating the absorption chiller such that the chiller is able to control the temperature of the hot water source regardless of the outside ambient air temperature.

SUMMARY

[0005] The present disclosure relates to a method and system for controlling a simultaneous heating and cooling absorption chiller having an absorber, a high stage generator, a low stage generator, a heat exchanger, a condenser, and an evaporator. The system includes a first flow passage for delivering refrigerant in vaporized form from the high stage generator to the low stage generator, and a second flow passage for delivering refrigerant in vaporized form from the high stage generator to the heat exchanger. A first valve is configured for controlling an amount of refrigerant in liquid form flowing from the low stage generator to the evaporator. A second valve is configured for controlling an amount of refrigerant in liquid form flowing from the heat exchanger back to the high stage
generator. The system further includes a controller for controlling operation of the first and second valves as a function of a temperature of at least one of a hot water source, the refrigerant in liquid form and an absorbent solution.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of an exemplary embodiment of a simultaneous heating and cooling absorption chiller, which includes a high stage generator, a low stage generator, and a heat exchanger configured for increasing a temperature of a hot water source flowing through the heat exchanger.

FIG. 2 is a schematic diagram of the heat exchanger of FIG. 1, including a control valve for regulating a flow of condensate from the heat exchanger.

FIG. 3 is a schematic diagram of a portion of the chiller of FIG. 1, including a low stage generator, a condenser and a cooling water loop.

FIG. 4 is a schematic diagram of a control system for controlling operation of the absorption chiller of FIG. 1.

DETAILED DESCRIPTION

FIG. 1 is a schematic diagram of absorption chiller system 10, which includes evaporator 12, absorber 14, high stage generator 16, low stage generator 18, condenser 20, high temperature solution heat exchanger 22, low temperature solution heat exchanger 24, and auxiliary heat exchanger 26. In the exemplary embodiment of FIG. 1, chiller system 10 is a double-effect absorption chiller with simultaneous heating and cooling capabilities, and as such, system 10 may be used to supply heating and cooling to a building. It is recognized that the method and system described herein for controlling a temperature of a hot water source in chiller system 10 may also apply to any type of absorption chiller having simultaneous heating and cooling capabilities, including, but not limited to, a single-effect or a triple-effect absorption chiller.

Chiller system 10 is configured to provide cooling to a building by decreasing a temperature of chilled water source 28, which passes through evaporator 12. System 10 is able to simultaneously provide heating to the building by increasing a temperature of hot water source 30, which passes through auxiliary heat exchanger 26. As is commonly used with absorption chillers, system 10 also includes cooling water loop 32 for flowing water from a cooling tower through absorber 14 and condenser 20 such that the cooling water is used for heat removal.

As is known in the art, absorption chiller systems, like system 10, are configured to use an absorbent solution, such as lithium bromide, and a refrigerant, such as...
water, to provide a cooling and/or a heating effect. Although chiller system 10 is described using lithium bromide and water, it is recognized that other combinations (for example, water as the absorbent and ammonia as the refrigerant) may alternatively be used in system 10.

[0013] Evaporator 12 is configured to receive refrigerant in liquid form (i.e. water) from condenser 20 and store the water in evaporator sump 34. With the use of refrigerant pump 36, evaporator 12 pumps water from sump 34 to sprayer 38, located at a top of evaporator 12, or to a dripper system in evaporator 12. As a result of chilled water 28 running through tubes inside evaporator 12, water from sprayer 38 is vaporized, and chilled water 28 decreases in temperature. As shown, system 10 is a closed loop system and maintained in a vacuum such that water from sprayer 38 boils at a lower temperature. The refrigerant (water), now in vaporized form, travels to absorber 14 through eliminator 40, at which point the water is absorbed by a concentrated lithium bromide solution being sprayed through sprayer 42 at a top of absorber 14. A diluted lithium bromide solution then is delivered to high stage generator 16 using solution pump 44. High and low temperature solution heat exchangers 22 and 24, which transport lithium bromide solution to and from low stage generator 18, increase a temperature of the diluted lithium bromide solution flowing to generator 16, and thereby increase an efficiency of generator 16.

[0014] Exhaust gas is supplied to high stage generator 16 to boil water from the lithium bromide solution, thus generating steam. In the exemplary embodiment of FIG. 1, exhaust gas is supplied from a microturbine or another type of prime mover. A benefit of system 10 is that it utilizes waste heat from another component used in the building. It is recognized that other types of heat sources may be used for supplying heat energy to generator 16. For example, in alternative embodiments, generator 16 may be direct-fired, steam fired or hot-water driven. Steam generated by generator 16 may then be directed to low stage generator 18 and to auxiliary heat exchanger 26. Moreover, steam from generator 16 may also reside in overflow piping 46.

[0015] Steam from high stage generator 16 flows to a tube side of low stage generator 18. Lithium bromide solution from high stage generator 16 flows through heat exchanger 22 and then flows to a shell side of low stage generator 18. The lithium bromide solution in generator 18 then boils off additional steam due to transferred heat from the steam on the tube side of generator 18. The additional steam on the shell side of generator 18 then travels to condenser 20 through eliminator 48 located between generator 18 and condenser 20. In condenser 20, cooling water 32 flows through a tube side of condenser 20. As the steam
from generator 18 enters the shell side of condenser 20, the steam condenses and the condensate is recycled back to evaporator 12.

[0016] Steam in the tube side of generator 18 condenses and the condensate is recycled back to evaporator 12, along with the condensate from condenser 20. Lithium bromide from generator 18, which is again at a high concentration, flows through heat exchanger 24 and is recycled back to absorber 14. The cycle is repeated as concentrated lithium bromide is sprayed in absorber 14, thereby absorbing water from evaporator 12.

[0017] Because system 10, in the exemplary embodiment of FIG. 1, is a simultaneous heating and cooling absorption chiller, system 10 also includes auxiliary heat exchanger 26, which may be used for heating. Steam from high stage generator 16 travels to a shell side of auxiliary heat exchanger 26, where the steam condenses, thus transferring heat to hot water source 30 flowing through a tube side of heat exchanger 26. After the steam condenses, the liquid condensate is recycled back to generator 16, where it may be reabsorbed by the lithium bromide solution in generator 16.

[0018] In the embodiment shown in FIG. 1, chiller system 10 includes overflow piping 46 connected between high stage generator 16 and absorber 14. Overflow piping 46, used in conjunction with steam trap 50, may be used to recycle excess absorbent solution in generator 16, which may accumulate under certain operating conditions, back to absorber 14. As also shown in FIG. 1, system 10 includes liquid level sensors 52 for monitoring a level of refrigerant in evaporator sump 34 to control operation of refrigerant pump 36. It is recognized that overflow piping 46, steam trap 50 and sensors 52 are not required in chiller system 10, but may be used for improving operation of system 10, particularly under a low cooling or heating load.

[0019] As shown in FIG. 1, system 10 includes three main valves that are used to control operation of system 10 - diverter valve 70 (also referred to as CV1), heat exchanger control valve 72 (also referred to as CV2), and low stage generator control valve (also referred to as CV3). Valve 70 (CV1) is configured to regulate an amount of exhaust gas supplied to high stage generator 16 based on the heating and/or cooling demands on system 10. Valve 72 (CV2) is configured to regulate an amount of liquid condensate in heat exchanger 26 recycled back to generator 16, as a function of the heating demand. Valve 74 (CV3) is configured to regulate an amount of liquid condensate in low stage generator 18 recycled back to evaporator 12, based on the heating and/or cooling demands and the conditions inside high stage generator 16. System 10 also includes bypass loop 80, configured in parallel with heat exchanger 26, and valve 82, both of which are described in
further detail below. It is recognized that bypass loop 80 and valve 82 are not required in chiller system 10, but may be used for improving operation of system 10, particularly in an absence of a heating demand. It is recognized that additional valves not specifically shown in FIG. 1 or described herein are included in system 10.

[0020] FIG. 2 is a schematic diagram of heat exchanger 26 from FIG. 1. Heat exchanger 26 is used to increase a temperature of hot water 30 passing through heat exchanger 26 via heat exchanger inlet 84 and heat exchanger outlet 90. In one embodiment, heat exchanger 26 may be a shell and tube type heat exchanger, in which case hot water 30a entering through inlet 84 is directed through multiple tubes 86 inside heat exchanger 26.

Steam from generator 16 enters a shell side of heat exchanger 26 through piping 88. As such, heat from the steam is transferred to hot water 30 and the steam condenses on the outside of tubes 86 to form a liquid condensate. Generally speaking, when steam from generator 16 is entering the shell side of heat exchanger 26 and hot water 30 is passing through the tube side, an outlet temperature $T_{HE\_OUT}$ of hot water 30b at outlet 90 is greater than an inlet temperature $T_{HE\_IN}$ of hot water 30a at inlet 84.

[0021] Valve 72 (CV2) is configured to regulate an amount of heat transferable to hot water 30. If CV2 is open, the liquid condensate (which was steam from generator 16) is directed to flow out of heat exchanger 26 and back to generator 16 through piping 92. Conversely, if CV2 is closed, the liquid condensate builds up inside heat exchanger 26. A heating capacity of heat exchanger 26 is a function of an amount of condensate inside heat exchanger 26. As condensate accumulates inside heat exchanger 26, less steam is entering heat exchanger 26; consequently, there is less heat transfer to hot water 30. If CV2 remains closed over a period of time, the condensate eventually may occupy all of the space inside heat exchanger 26 such that heat exchanger 26 is not capable of providing any heating to hot water 30. In summary, the heating capacity of heat exchanger 26 is a function, in part, of the position or state of CV2.

[0022] CV2 controls the outlet temperature $T_{HE\_OUT}$ of hot water 30b by controlling an amount of condensate inside heat exchanger 26, based on a set point temperature $T_{HE\_SET\_PT}$ for hot water 30. For example, during a heating demand, the set point temperature $T_{HE\_SET\_PT}$ may be equal to 175°F. Therefore, CV2 is positioned and adjusted as necessary so that $T_{HE\_OUT}$ remains essentially equal to 175°F. Because system 10 is a simultaneous heating and cooling absorption chiller, system 10 may be operating in some cases when there is a cooling demand, but no heating demand. (This includes those scenarios in which the heating and cooling demands on system 10 are frequently fluctuating.) Under those conditions, hot water
30 may continue to be pumped through heat exchanger 26, even though the building is not requesting any heating.

[0023] The set point temperature \( T_{HE \, SET \, PT} \) for the hot water outlet is adjusted to reflect changes in the heating demand. When there is no heating demand, controller 112 of system 10 (described below in reference to FIG. 4) may decrease \( T_{HE \, SET \, PT} \) and adjust diverter valve 70 (CV1) to supply less heat to generator 16. Less heat results in a generation of less steam and less heat transfer to hot water 30. The controller may also close CV2 in order to the decrease the heating capacity of heat exchanger 26 by accumulating liquid condensate inside heat exchanger 26. Despite these adjustments, as a pump continues to circulate hot water 30 through heat exchanger 26, residual energy from the pump, as well as friction heat, may cause outlet temperature \( T_{HE \, OUT} \) to increase above the set point temperature \( T_{HE \, SET \, PT} \). If this hot water energy is not consumed by a building heating load, the outlet temperature \( T_{HE \, OUT} \) may eventually reach an undesirably high temperature.

[0024] Bypass loop 80 may be used to reject (i.e. transfer) heat from hot water 30 when outlet temperature \( T_{HE \, OUT} \) rises above a predetermined level. Bypass loop 80 is configured in parallel with heat exchanger 26, and includes first flow passage 96, second flow passage 98 and a heat rejection radiator (not shown). As shown in FIG. 2, first flow passage 96 is connected to inlet 84 of heat exchanger 26 and second flow passage 98 is connected to outlet 90 so that at least a portion of hot water 30 may flow through bypass loop 80. The heat rejection radiator of bypass loop 80 is designed to be located inside piping of cooling water loop 32 (see FIG. 1). When water 30 flows through the heat rejection radiator, heat from water 30 is transferred to cooling water circulating through cooling water loop 32. Valve 82 (see FIG. 1) is located within first flow passage 96, and is configured to regulate a flow of hot water 30 through bypass loop 80. In alternative embodiments, instead of using the heat rejection radiator, heat may be transferred or rejected from hot water 30 using other devices or methods. For example, heat rejection may be made directly to the cooling tower or using an additional heat exchanger not included in the embodiment of system 10.

[0025] Bypass loop 80 may be used in those scenarios where system 10 does not have a heating demand and the outlet temperature \( T_{HE \, OUT} \) rises to an undesirable value. In contrast, operation of chiller system 10 also includes those scenarios in which the building has a heating demand and system 10 may have difficulty maintaining the outlet temperature \( T_{HE \, OUT} \) at the set point \( T_{HE \, SET \, PT} \). As described above, valve 72 (CV2) may be used to control an amount of heating provided by system 10 by controlling the flow of condensate out of heat exchanger 26. However, in some scenarios, even if valve 72 is fully open, outlet
temperature the outlet at outlet 90 may be less than the set point temperature \( T_{\text{OUT}} \). This means that steam from high stage generator 16 is not transferring enough heat to hot water 30 to increase the temperature of water 30 to the set point temperature \( T_{\text{SET PT}} \). This may commonly occur when an outside ambient air temperature is low. As described below in reference to FIGS. 3 and 4, valve 74 (CV3) may be used to adjust conditions inside high stage generator 16 (i.e. pressure) so that the outlet temperature \( T_{\text{OUT}} \) is able to reach the set point temperature \( T_{\text{SET PT}} \), regardless of the outside ambient air temperature.

[0026] FIG. 3 is a schematic diagram of a portion of chiller system 10 of FIG. 1, including low stage generator 18, condenser 20, and a portion of cooling water loop 32. As described above, cooling water loop 32 is configured to contain cooling water from a cooling tower. Cooling water loop 32 passes through absorber 14 (see FIG. 1) and then through condenser 20. The cooling water is then recycled back to the cooling tower. As also described above in reference to FIG. 1, low stage generator 18 is configured to receive steam from high stage generator 16 (via piping 122), which flows to the tube side of low stage generator 18. Lithium bromide solution from high stage generator 16 flows through piping 124 to the shell side of low stage generator 18. As heat is transferred from the steam (tube side) to the lithium bromide solution (shell side), the steam undergoes a phase change to liquid condensate, and the lithium bromide solution boils off additional steam that then travels through eliminator 48 to condenser 20. The concentrated lithium bromide solution is then recycled back to absorber 14 through piping 126. The liquid condensate (refrigerant) in the tube side of generator 18 exits generator 18 through piping 128, which is connected to valve 74 (CV3). The liquid condensate ultimately flows back to evaporator 12 through piping 130.

[0027] Steam from the shell side of generator 18 passes through to condenser 20. As cooling water in cooling water loop 32 passes through condenser 20, heat is transferred from the steam to the cooling water such that the steam in condenser 20 forms a liquid condensate. This second liquid condensate is recycled back to evaporator 12 through piping 130, along with the condensate from generator 18.

[0028] Under normal or typical operating conditions, a temperature of the cooling water at the inlet of cooling water loop 32 (see FIG. 1) may be approximately 85°F and a temperature at the outlet of cooling water loop 32 (an outlet of condenser 20) may be approximately 95°F. Because the cooling tower is exposed to ambient air, the inlet temperature of the cooling water is directly affected by an outside ambient air temperature. A lower cooling water temperature impacts the condensation process inside condenser 20.
Specifically, an internal pressure inside condenser 20 directly correlates to a temperature of the cooling water. When the cooling water is at a lower temperature, it results in a lower pressure inside condenser 20. (Note that chiller system 10 is in a vacuum and all components within system 10 are at low pressures. Any pressure differentials described herein are relative.)

[0029] A lower pressure inside condenser 20 results in a lower pressure within other components of chiller system 10, such as high stage generator 16 and low stage generator 18. If chiller system 10 only had a cooling demand, lower pressure conditions inside system 10 may not be problematic. However, a lower pressure inside high stage generator 16 causes steam from the lithium bromide solution to boil at a lower temperature. The lower temperature steam then travels from high stage generator 16 to heat exchanger 26 (see FIG. 1). Since the temperature of the steam is lower, the steam transfers less heat to hot water 30 passing through heat exchanger 26. In that case, it may not be possible for the outlet temperature $T_{HE\_OUT}$ to reach the set point temperature $T_{HE\_SET\_PT}$ (for example, 175°F).

[0030] Control valve 74 (see FIG. 3), which is located at an outlet of low stage generator 18, may be used to control the pressure inside high stage generator 16. As such, control valve 74 may indirectly control the outlet temperature $T_{HE\_OUT}$ of hot water 30. When control valve 74 (CV3) is fully open, condensate from the tube side of generator 18 is able to freely flow through piping 128, and ultimately through piping 130 back to evaporator 12. In that case, there is essentially no change in pressure between high stage generator 16 and condenser 20. As mentioned above, when the pressure in condenser 20 is low, the pressure in generator 16 is also low. Conversely, when control valve 74 (CV3) is closed at least partially, the flow of condensate through piping 128 is limited by an orifice created by partially closing valve 74. The result is a pressure differential between a location upstream of valve 74 and a location downstream of valve 74. More specifically, closing valve 74 results in a back pressure that increases a pressure inside high stage generator 16. The higher pressure in generator 16 increases a temperature of the steam boiling inside generator 16, and thus facilitates greater heat transfer from the steam to hot water 30 in heat exchanger 26.

[0031] As explained below in reference to FIG. 4, controller 112 controls a position of valve 74 in order to maintain the outlet temperature $T_{HE\_OUT}$ of hot water 30 essentially equal to the set point temperature $T_{HE\_SET\_PT}$. Controller 112 may control valve 74 based on various parameters within system 10, as explained below. For example, an input parameter to controller 112 is a temperature $T_{G2\_OUT}$ of the liquid condensate (refrigerant) at an outlet of
low stage generator 18. At least one temperature sensor located upstream of valve 74, in or around piping 128, may be used for measuring $T_{G2\text{OUT}}$.

[0032] FIG. 4 is a schematic diagram of control system 110 for controlling operation of chiller system 10. System 110 includes controller 112, inputs 114 to controller 112 and outputs 116. It is recognized that control system 110 includes additional inputs and outputs that are not included in FIG. 4 for clarity.

[0033] Inputs 114 include cooling demand 118, heating demand 120, THE OUT, THE SET PT, $T_{ABS\text{OUT}}$, $T_{O2\text{OUT}}$, and $T_{E2\text{SET PT}}$. Because chiller system 10 is configured for simultaneous heating and cooling, system 10 may have a cooling demand and a heating demand at the same time. At other times, system 10 may be operating under either a cooling demand or a heating demand. Moreover, system 10 may experience frequent fluctuations in the cooling and/or the heating demand. Based on cooling demand 118 and heating demand 120, controller 112 controls a position of valve 70 (CV1), which supplies heat (i.e., waste gas) to generator 16. So long as the total demand (heating plus cooling) does not exceed a maximum value, controller 112 may not be required to designate a heating priority or a cooling priority. However, if the total demand is greater than the maximum value, controller 12 may operate as a function, at least in part, of whether system 10 has a heating priority or a cooling priority. In either case, when the total demand is at or above a maximum value, control valve 70 (CV1) is fully open and controller 112 adjusts valves 72 and 74 to provide the required heating and/or cooling.

[0034] Because valve 72 (CV2) is configured to regulate a flow of condensate exiting heat exchanger 26, valve 72 controls an ability of heat exchanger 26 to transfer heat to hot water 30 passing through heat exchanger 26. A position of valve 72 (CV2) is controlled, in part, as a function of the temperature $T_{E2\text{OUT}}$ of hot water 30b at outlet 90. Temperature THE OUT is compared to a set point temperature THE SET PT for the hot water, which may be, for example, commonly set at 175°F. Thus, as shown in FIG. 4, $T_{E2\text{OUT}}$ and $T_{H2E3\text{SET PT}}$ are both inputs to controller 112.

[0035] As described above, bypass loop 80 is configured to redirect at least a portion of hot water 30 from heat exchanger 26 to the heat rejection radiator if the temperature $T_{HE\text{OUT}}$ of hot water 30 at outlet 90 of heat exchanger 26 is too high. As described above, controller 112 adjusts CV2 to control temperature $T_{HE\text{OUT}}$, based on the set point temperature $T_{HE\text{SET PT}}$. Therefore, the heat rejection radiator is usually not used until temperature $T_{HE\text{OUT}}$ is above a predetermined value that is greater than the set point temperature $T_{HE\text{SET PT}}$. Valve 82 controls a flow of hot water 30 to the radiator, and is controlled by controller 112. When $T_{HE}$
$T_{O UT}$ rises above the predetermined value, controller 112 opens valve 82 so that water 30 is able to flow through bypass loop 80. The predetermined value is equal to a sum of the set point temperature $T_{HE \, SET \, PT}$ and a marginal value. For example, if $T_{HE \, SET \, PT}$ is equal to 175°F and the marginal value is equal to ten degrees, controller 112 opens valve 82 if $T_{OUT}$ is greater than 185°F. Valve 82 may then be closed when $T_{HE \, OUT}$ decreases to a temperature that is less than or equal to the predetermined value. Control system 110 includes at least one temperature sensor located around outlet 90 of heat exchanger 26 for measuring $T_{HE \, OUT}$.

[0036] Inputs 114 also include $T_{G2 \, OUT}$, which, as mentioned above, is a temperature of the liquid condensate (refrigerant) exiting a tube side of generator 18, and $T_{ABS \, OUT}$, which is a temperature of the absorbent solution (i.e. lithium bromide) exiting absorber 14. $T_{G2 \, OUT}$ and $T_{ABS \, OUT}$ may be monitored, along with $T_{HE \, OUT}$, by controller 112 to determine a position of valve 74 (CV3). As described above, valve 72 (CV2) is used to control the outlet temperature $T_{HE \, OUT}$ of hot water 30, and consequently control an amount of heating provided by heat exchanger 26. However, in some scenarios (for example—a low outside ambient air temperature), even if valve 72 (CV2) is fully open (i.e. to maximize heating capacity of heat exchanger 26), the outlet temperature $T_{HE \, OUT}$ of hot water 30 may be less than the set point temperature $T_{HE \, SET \, PT}$. In that case, adjustments may be made to valve 74 (CV3), based on $T_{G2 \, OUT}$, $T_{ABS \, OUT}$, and $T_{HE \, OUT}$, to increase the outlet temperature $T_{HE \, OUT}$ and bring it closer to $T_{HE \, SET \, PT}$. As further described below, inputs 114 may also include a set point temperature for liquid condensate exiting low stage generator 18 (referred to as $T_{G2 \, SET \, PT}$). The condensate set point temperature $T_{G2 \, SET \, PT}$ is calculated by controller 112 as a function of inputs 114 to controller 112, and thus $T_{G2 \, SET \, PT}$ varies depending on conditions inside system 10. The set point temperature $T_{G2 \, SET \, PT}$ may be determined using an algorithm described below. Control system 110 includes at least one temperature sensor at an outlet of absorber 14 for measuring the temperature of the absorbent solution $T_{ABS \, OUT}$, and at least one sensor at an outlet of generator 18 for measuring the temperature of the steam condensate, $T_{G2 \, OUT}$. 

[0037] Controller 112 includes a control algorithm that determines when and how valve 74 (CV3) is adjusted. Inputs 114 to controller 112 include the set point temperature $T_{G2 \, SET \, PT}$ for steam condensate at an outlet of low stage generator 18 and an actual temperature $T_{G2 \, OUT}$ of the steam condensate at the outlet of generator 18. Controller 112 controls a position of valve 74 so that $T_{G2 \, OUT}$ is essentially equal to $T_{G2 \, SET \, PT}$ (assuming a tolerance range). Valve 74 is opened or closed (incrementally) based on a difference between $T_{G2 \, SET \, PT}$ and $T_{G2 \, OUT}$. If $T_{G2 \, OUT}$ is greater than $T_{G2 \, SET \, PT}$, then controller 112 starts opening
valve 74 until T G 2 OUT decreases to T G 2 SET PT. On the other hand, if T G 2 OUT is less than T G 2 SET PT, then controller 112 starts closing valve 74 until T G 2 OUT increases to T G 2 SET PT.

[0038] In a preferred embodiment, the control algorithm includes three equations to calculate the set point temperature T G 2 SET PT of the condensate (liquid refrigerant) exiting low stage generator 18. As illustrated by Equations 1 and 2 below, the set point temperature T G 2 SET PT is a function of the temperature of the lithium bromide solution exiting absorber 14 (T A BS OUT), the actual outlet temperature of water 30 exiting heat exchanger 26 (T HE OUT), and a valve position feedback percentage for valve 72 (referred to as VF cv2), which is expressed as a decimal value.

[0039] **Equation 1:** IF (T A BS s OUT + G2 factor A) < (T HE o UT + G2 factor B), THEN T G 2 SET PT = (THE OUT + G2 factor B)

[0040] **Equation 2:** IF (T A BS O UT + G2 factor A) ≥ (T HE O UT + G2 factor B), THEN T G 2 SET PT = (THE OUT + G2 factor B) + ((1.0-VF cv2) * ((TABS OUT + G2 factor A) - (T HE OUT + G2 factor B)))

[0041] **Equation 3:** IF T G 2 SET PT > 211, THEN T G 2 SET PT = 211

[0042] In Equations 1 and 2, G2 factor A is a constant value ranging between 80 and 120, and G2 factor B is a constant value ranging between 2 and 30.

[0043] As mentioned above, if T C 2 O U F is greater than T G 2 SET PT, then valve 74 (CV3) is incrementally opened until T G 2 OUT is equal to T G 2 SET PT. If T G 2 OUT is less than T G 2 SET PT, then valve 74 (CV3) is incrementally closed until T G 2 O U F is equal to T G 2 SET PT.

[0044] Chiller system 10 is described above using lithium bromide as the absorbent solution and water as the refrigerant. As mentioned above, other combinations, such as ammonia and water, may also be used in system 10. In those embodiments, the control method described herein may also be used to control the outlet temperature T H E O U F of hot water 30 by controlling valve 74. It is recognized that Equations 1-3 may vary depending on the absorbent solution and refrigerant. For example, in a system using ammonia and water, the ranges for G2 factor A and G2 factor B may be different than the ranges provided above.

[0045] In the exemplary embodiment shown in FIGS. 1-3, valves 72 and 74 are bellows type valves. It is recognized that other types of valves for regulating fluid flow may be used in system 10. In a preferred embodiment, controller 112 includes a proportional integral derivative (PID) function and a limiter for controlling a position and rate motion of valves 72 and 74.

[0046] The set point temperature T H E S ET PT for hot water 30 may be determined by a user based, in part, on the building conditions and the heating demand. Thus, the user may
input the hot water set point $T_{\text{SET PT}}$ into control system 110 and change $T_{\text{SET PT}}$ as necessary or as desired. In contrast, the set point temperature $T_{G2 \text{ SET PT}}$ for the condensate exiting low stage generator 18 is calculated by controller 112, based on other inputs 114, such as $T_{\text{AB OUT}}$ and $T_{\text{HE OUT}}$. Thus, the set point temperature $T_{G2 \text{ SET PT}}$ of the condensate may fluctuate frequently based on conditions in chiller system 10. Control system 110 then uses a comparison between $T_{G2 \text{ OUT}}$ and $T_{G2 \text{ SET PT}}$ to adjust valve 74, in order to maintain the outlet temperature $T_{\text{OUT}}$ essentially equal to the set point temperature $T_{\text{HE SET PT}}$ for hot water 30.

[0047] In the embodiment shown in FIGS. 1-3 and described above, chiller system 10 is a double-effect absorption chiller. It is recognized that this control method may be used in other types of absorption chillers, such as a single-effect or a triple-effect absorption chiller. The control method described herein may be used to control a hot water temperature in those other systems by monitoring and controlling pressure and/or temperature inside the absorption chiller in similar locations as compared to what was shown and described above for chiller system 10.

[0048] Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.
CLAIMS:

1. A control system for operating an absorption chiller capable of simultaneous heating and cooling and having an absorber, a high stage generator, a low stage generator, a heat exchanger, a condenser, and an evaporator, the control system comprising:
   a) a first flow passage for delivering refrigerant in vaporized form from the high stage generator to the low stage generator;
   b) a second flow passage for delivering refrigerant in vaporized form from the high stage generator to the heat exchanger;
   c) a first valve for controlling an amount of refrigerant in liquid form flowing from the low stage generator to the evaporator;
   d) a second valve for controlling an amount of refrigerant in liquid form flowing from the heat exchanger to the high stage generator; and the controller for controlling operation of the first and second valves.

2. The control system of claim 1 wherein the second valve is configured to control an outlet temperature of hot water passing through the heat exchanger.

3. The control system of claim 1 wherein the first valve is configured to control an amount of pressure in the high stage generator.

4. The control system of claim 1 wherein the second valve is controlled as a function of an outlet temperature of hot water passing through the heat exchanger and a hot water set point temperature.

5. The control system of claim 1 wherein the first valve is controlled as a function of a temperature of the refrigerant in liquid form exiting the low stage generator and a refrigerant set point temperature.

6. The control system of claim 5 wherein the controller calculates the refrigerant set point temperature as a function of at least one of a temperature of an absorbent solution exiting the absorber, a temperature of hot water exiting the heat exchanger, and a position of the second valve.

7. The control system of claim 1 further comprising:
   a) a first sensor for monitoring an outlet temperature of hot water passing through the heat exchanger.

8. The control system of claim 1 further comprising:
   a) a second sensor for monitoring a temperature of an absorbent solution exiting the absorber.
9. The control system of claim 1 further comprising:
   a third sensor for monitoring a temperature of the refrigerant in liquid form exiting the
   low stage generator.

10. A system for controlling a temperature of a hot water source in an absorption chiller capable of simultaneous heating and cooling, the system comprising:
    an absorber configured to contain an absorbent solution and receive a refrigerant in vaporized form so that the absorbent solution absorbs the refrigerant to form a diluted absorbent solution;
    a high stage generator configured to receive the diluted absorbent solution and a heat source such that the refrigerant contained in the diluted absorbent solution is vaporized;
    a heat exchanger for providing heating and configured to receive the refrigerant in vaporized form from the high stage generator and pass hot water through the heat exchanger such that the refrigerant condenses to form a first condensate and thereby increases a temperature of the hot water;
    a low stage generator configured to receive the refrigerant in vaporized form the high stage generator and form a second condensate;
    at least one sensor for measuring a temperature of at least one of the absorbent solution exiting the absorber, the hot water exiting the heat exchanger, and the second condensate; and
    a device for controlling an amount of pressure in the high stage generator as a function of at least one measured temperature.

11. The system of claim 10 wherein the device is a valve for regulating a flow of the second condensate from the low stage generator.

12. The system of claim 11 further comprising:
    a controller for controlling operation of the valve as a function of a difference between a temperature of the second condensate exiting the low stage generator and a condensate set point.

13. The system of claim 12 wherein the condensate set point is calculated by the controller as a function of at least one of a temperature of the absorbent solution exiting the absorber and a temperature of the hot water at an outlet of the heat exchanger.
14. The system of claim 12 further comprising:
   a second valve for regulating a flow of the first condensate from the heat exchanger back to the high stage generator.

15. The system of claim 14 wherein the condensate set point is calculated by the controller as a function of a position of the second valve.

16. The system of claim 10 wherein the at least one sensor includes a sensor for measuring a temperature of the hot water exiting the heat exchanger.

17. The system of claim 10 wherein the at least one sensor includes a sensor for measuring a temperature of the absorbent solution exiting the absorber.

18. The system of claim 10 wherein the at least one sensor includes a sensor for measuring a temperature of the second condensate exiting the low stage generator.

19. A method of operating a simultaneous heating and cooling absorption chiller having an evaporator, an absorber, a high stage generator, a low stage generator, a heat exchanger and a condenser, the method comprising:

   vaporizing a refrigerant from an absorbent solution in the high stage generator;
   delivering the refrigerant in vaporized form to the heat exchanger;
   delivering the refrigerant in vaporized form to the low stage generator;
   flowing hot water through the heat exchanger such that the refrigerant in the heat exchanger condenses and thereby increases a temperature of the hot water flowing through the heat exchanger;
   varying a flow of the refrigerant in liquid form from the heat exchanger to the high stage generator; and
   varying a flow of the refrigerant in liquid form from the low stage generator.

20. The method of claim 19 wherein varying the flow of the refrigerant from the heat exchanger is performed by a controller as a function of a set point temperature for the hot water exiting the heat exchanger.

21. The method of claim 20 wherein the controller varies a position of a valve located between the heat exchanger and the high stage generator.

22. The method of claim 19 wherein varying the flow of the refrigerant from the low stage generator varies an amount of pressure in the high stage generator.

23. The method of claim 19 wherein varying the flow of the refrigerant from the low stage generator is performed by a controller as a function of at least one of a temperature of the liquid refrigerant exiting the low stage generator, a temperature of the hot water exiting
the heat exchanger, a temperature of an absorbent solution exiting the absorber, and a position of a first valve that regulates the flow of the refrigerant from the heat exchanger.

24. The method of claim 23 wherein the controller varies a position of a second valve located between the low stage generator and the evaporator.

25. The method of claim 19 further comprising:
sensing a temperature of at least one of the liquid refrigerant exiting the low stage generator, the hot water source exiting the heat exchanger, and an absorbent solution exiting the absorber.

26. A method of controlling a hot water temperature in an absorption chiller configured to enable simultaneous heating and cooling and having an evaporator, an absorber, a high stage generator, a low stage generator, a condenser, and a heat exchanger, the method comprising:
monitoring a temperature of an absorbent solution exiting the absorber and configured to flow to the high stage generator;
monitoring an outlet temperature of hot water passing through the heat exchanger;
monitoring a temperature of a first condensate exiting the low stage generator; and regulating a flow of the first condensate from the low stage generator as a function of at least one of the temperature of the absorbent solution exiting the absorber, the temperature of the hot water exiting the heat exchanger, the temperature of the first condensate exiting the low stage generator, and a set point temperature for the first condensate.

27. The method of claim 26 wherein regulating the flow of the first condensate from the low stage generator includes varying a position of a valve located between piping connecting the low stage generator to the condenser.

28. The method of claim 27 wherein the position of the valve is controlled by a controller.

29. The method of claim 26 wherein the set point temperature for the first condensate is calculated by a controller.

30. The method of claim 26 further comprising:
regulating a flow of a second condensate from the heat exchanger back to the high stage generator as a function of the temperature of the hot water exiting the heat exchanger and a set point temperature for the hot water.
# INTERNATIONAL SEARCH REPORT

**A. CLASSIFICATION OF SUBJECT MATTER**

**F25B 15/00(2006.01)1, F25B 29/00(2006.01)1, F25B 49/04(2006.01)1**

According to International Patent Classification (IPC) or to both national classification and IPC

# B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 8 F25B 15/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean Utility models and applications for Utility models since 1975

Japanese Utility models and applications for Utility models since 1975

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKIPASS (KIPO internal) "Keyword absorption chiller, heating, cooling, hot water, temperature, and similar terms"

# C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>JP 2007-003122 A (Sanyo Electric Co., Ltd) 11 January 2007</td>
<td>1, 2, 4, 7, 19, 20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8, 9, 25</td>
</tr>
<tr>
<td>A</td>
<td>Y</td>
<td>3, 5, 6, 18-24, 26-30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8, 9, 25</td>
</tr>
<tr>
<td>Y</td>
<td>JP 06-147682 A (Osaka Gas Co., Ltd) 27 May 1994</td>
<td>8, 9, 25</td>
</tr>
<tr>
<td></td>
<td>See abstract, description, paragraphs 29-36, figure 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>See abstract, figure 1</td>
<td></td>
</tr>
</tbody>
</table>

☐ Further documents are listed in the continuation of Box C

☒ See patent family annex

* Special categories of cited documents
  *A* document defining the general state of the art which is not considered to be of particular relevance
  *E* earlier application or patent but published on or after the international filing date
  *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)
  *O* document referring to an oral disclosure, use, exhibition or other means
  *P* document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

10 JANUARY 2008 (10.01.2008)

Date of mailing of the international search report

10 JANUARY 2008 (10.01.2008)

Name and mailing address of the ISA/KR

Korean Intellectual Property Office
920 Dunsan-dong, Seo-gu, Daejeon 302-701,
Republic of Korea

Facsimile No 82-42-472-7140

Authorized officer

KONG, Ho Jin

Telephone No 82-42-481-8310

Form PCT/ISA/210 (second sheet) (April 2007)
<table>
<thead>
<tr>
<th>Patent document cited in search report</th>
<th>Publication date</th>
<th>Patent family member(s)</th>
<th>Publication date</th>
</tr>
</thead>
<tbody>
<tr>
<td>JP 2007-003122 A</td>
<td>11.01.2007</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>JP 06-147682 A</td>
<td>27.05.1994</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP3128501B2</td>
<td>29.01.2001</td>
</tr>
</tbody>
</table>