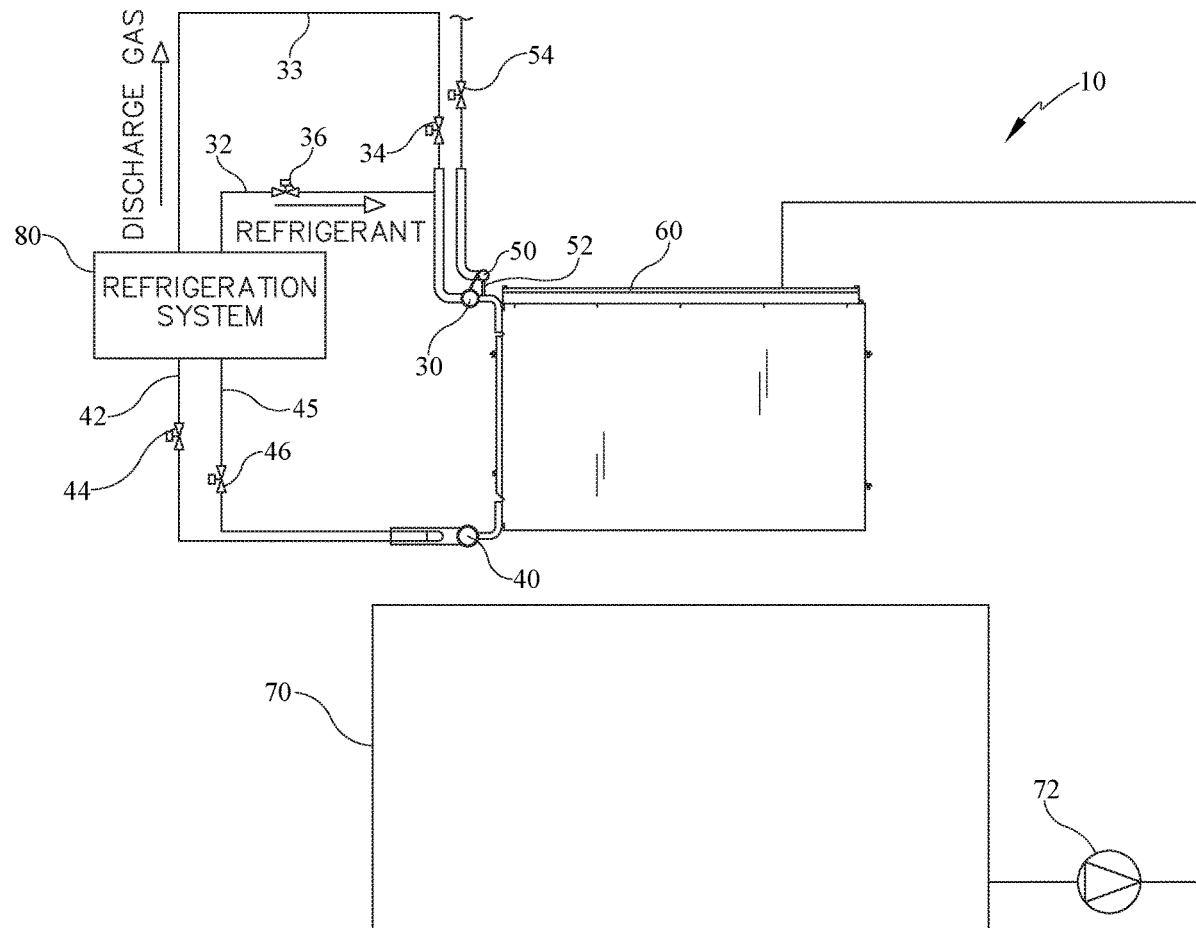




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Wilkins et al.(10) **Pub. No.: US 2021/0033327 A1**(43) **Pub. Date: Feb. 4, 2021**(54) **ICE MACHINE FOR AN ICE-BASED
THERMAL STORAGE SYSTEM****F25B 39/02** (2006.01)**F25B 41/04** (2006.01)(71) Applicant: **Weller Ice, LLC**, Louisville, KY (US)(72) Inventors: **Michael Alexander Wilkins**, Corydon,
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41/04 (2013.01); **F25C 2400/14** (2013.01);
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1, 2019.**Publication Classification**(51) **Int. Cl.**
F25C 1/12 (2006.01)
F25C 5/10 (2006.01)(57) **ABSTRACT**

An ice machine for an ice-based thermal storage system comprises a plurality of pillow plates arranged in a plate bank, wherein each of the plurality of pillow plates includes an inlet connection and an outlet connection, with the respective inlet connections connected to a feed header, and with the respective outlet connections connected to a suction header. A water distribution pan is positioned at a top of the plate bank, and a tank is positioned below the plate bank. As an evaporator, the ice machine causes ice to form on the pillow plates, which then falls into the tank. As a condenser, the ice machine transfers heat to water flowing over the pillow plates, such that water at an increased temperature falls into the tank and melts the ice in the tank.



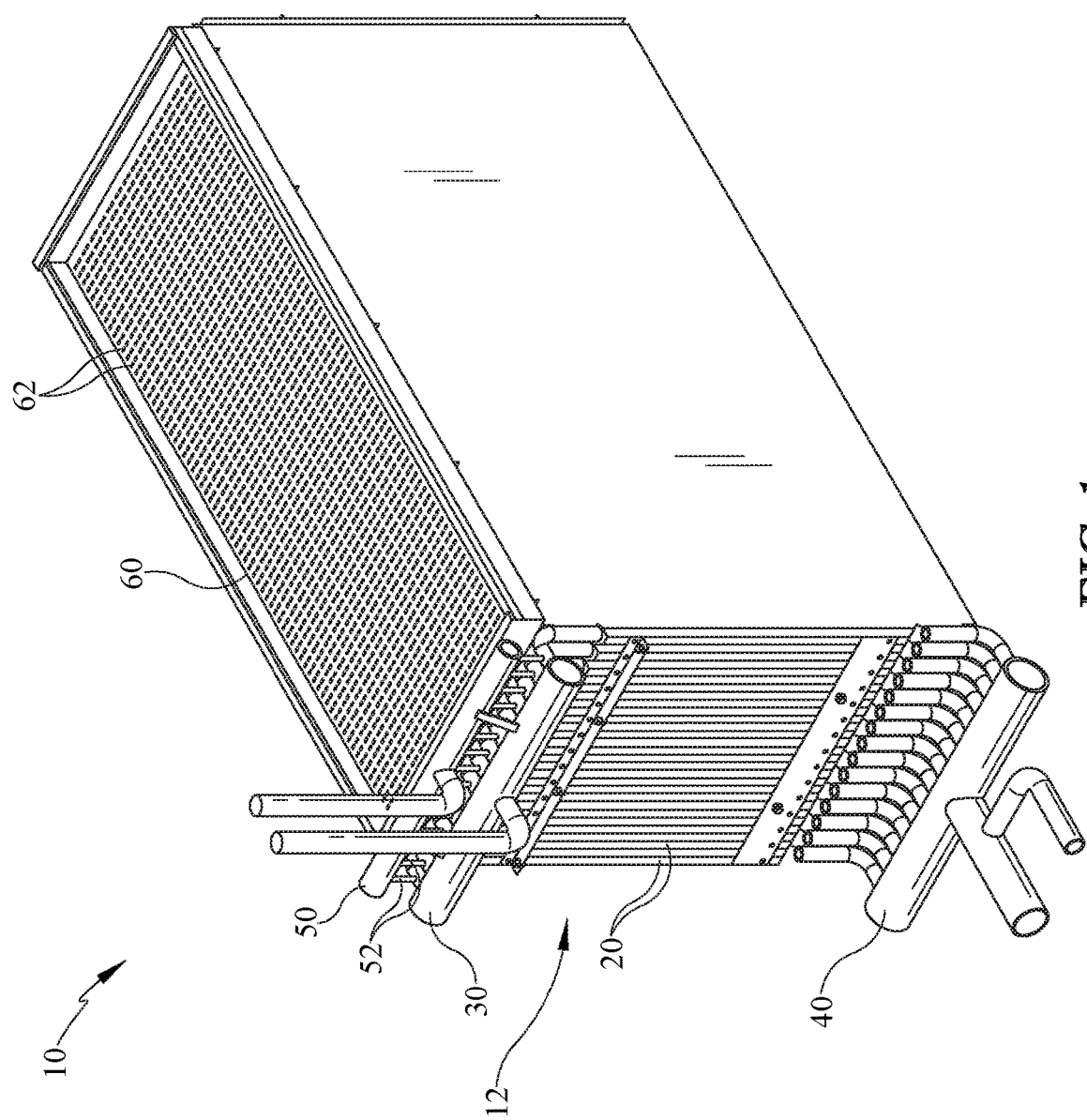


FIG. 1

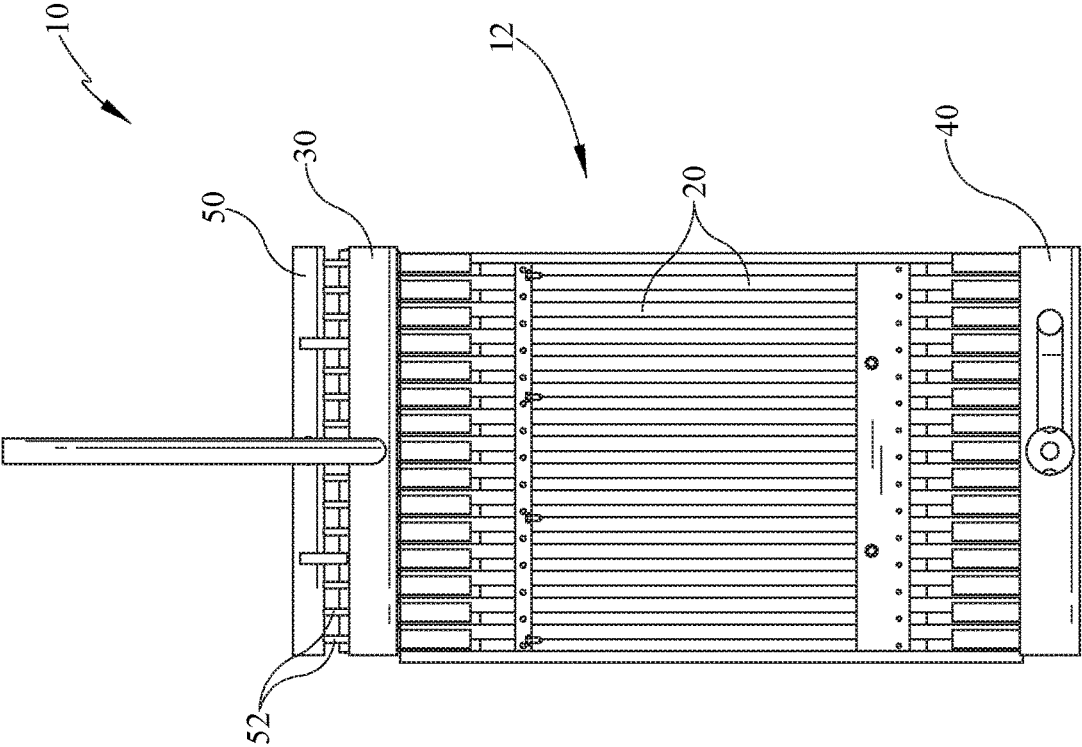
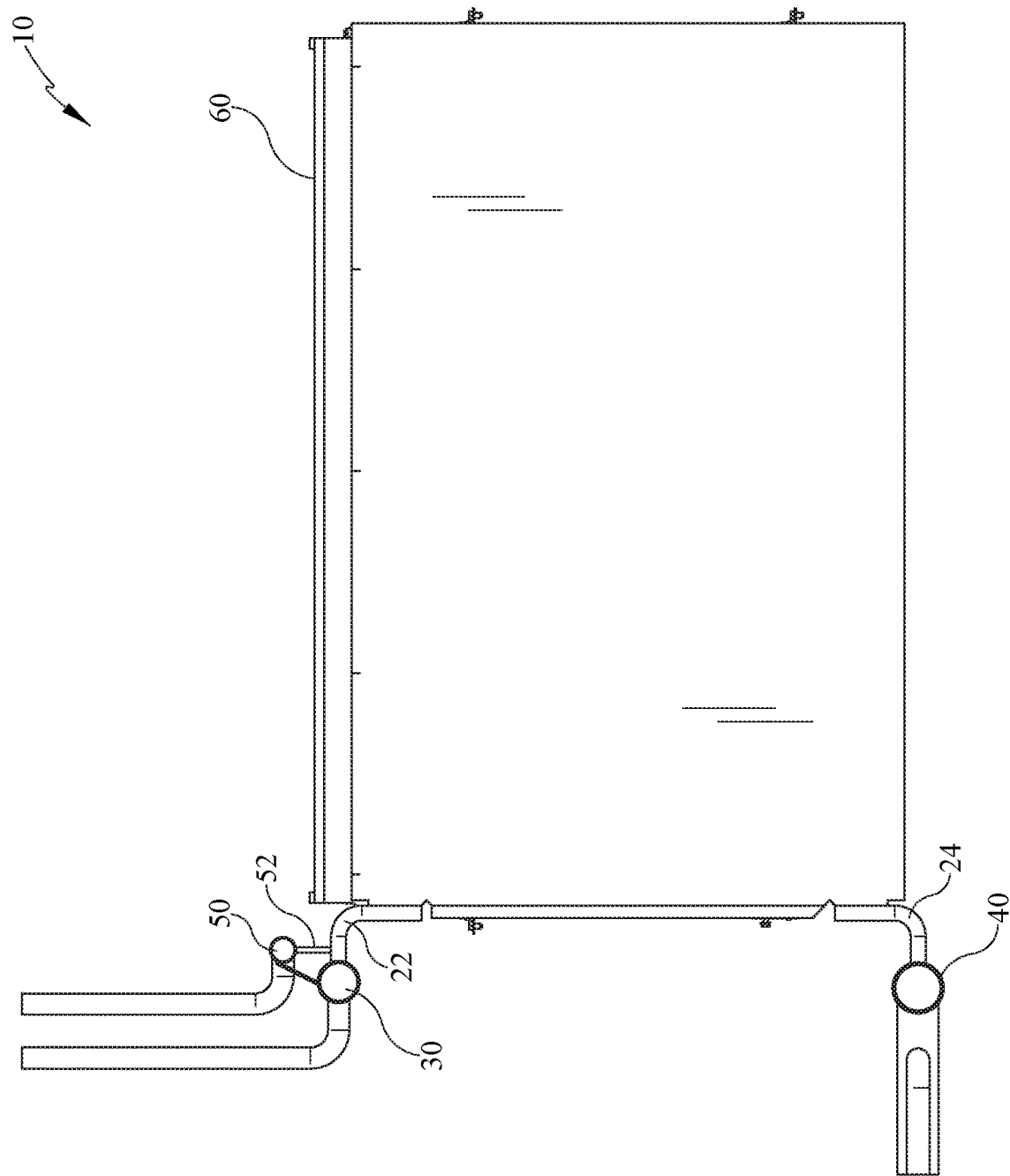
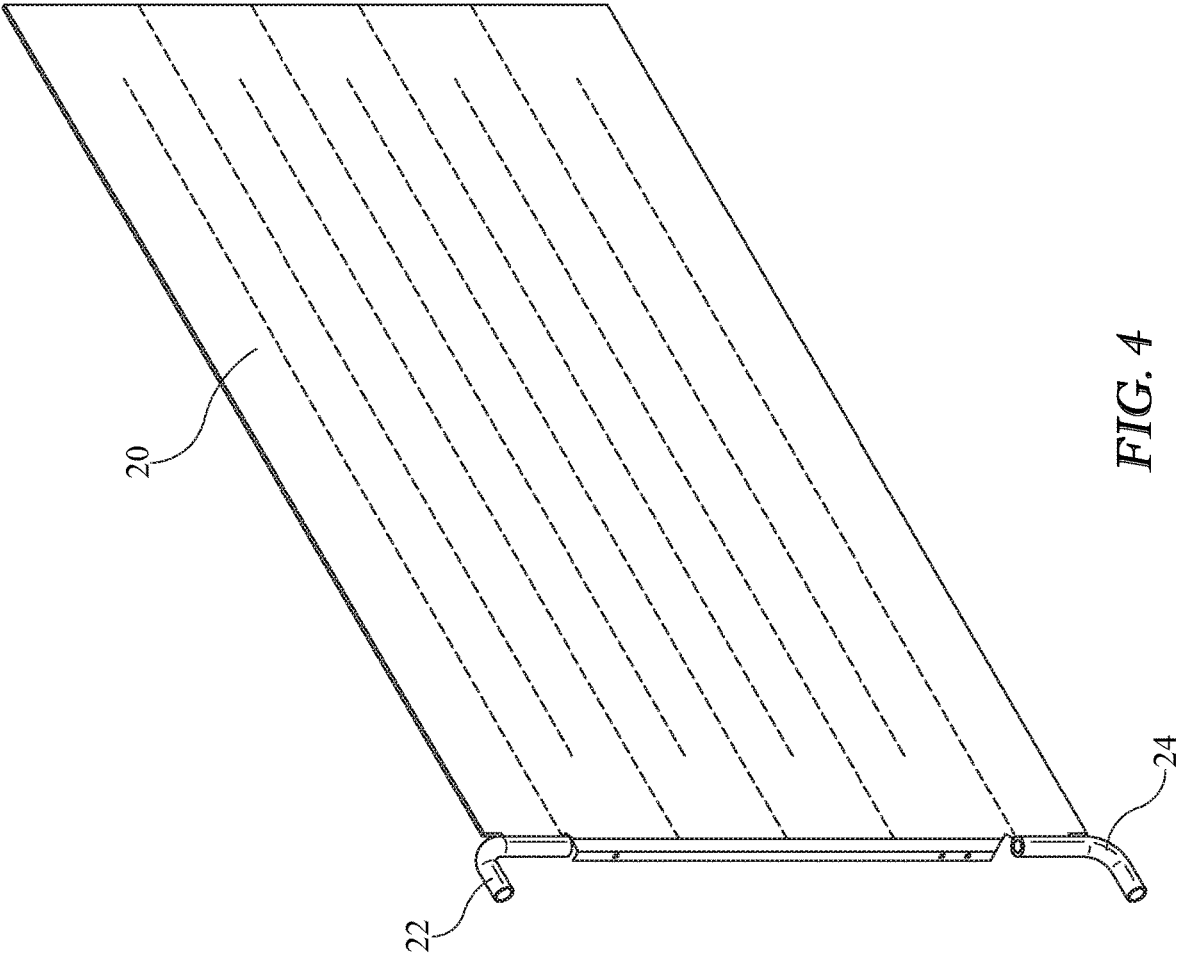


FIG. 2





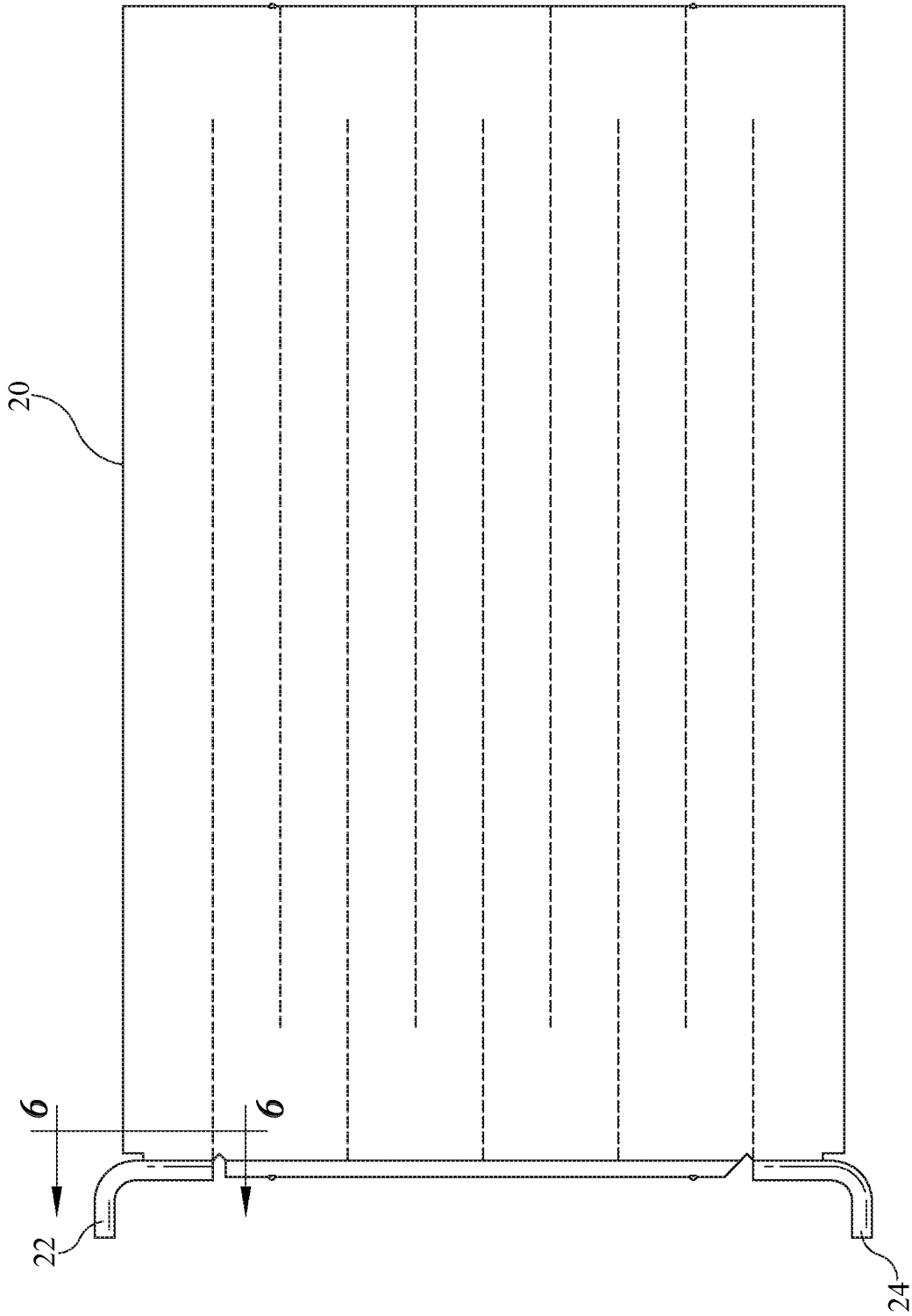


FIG. 5

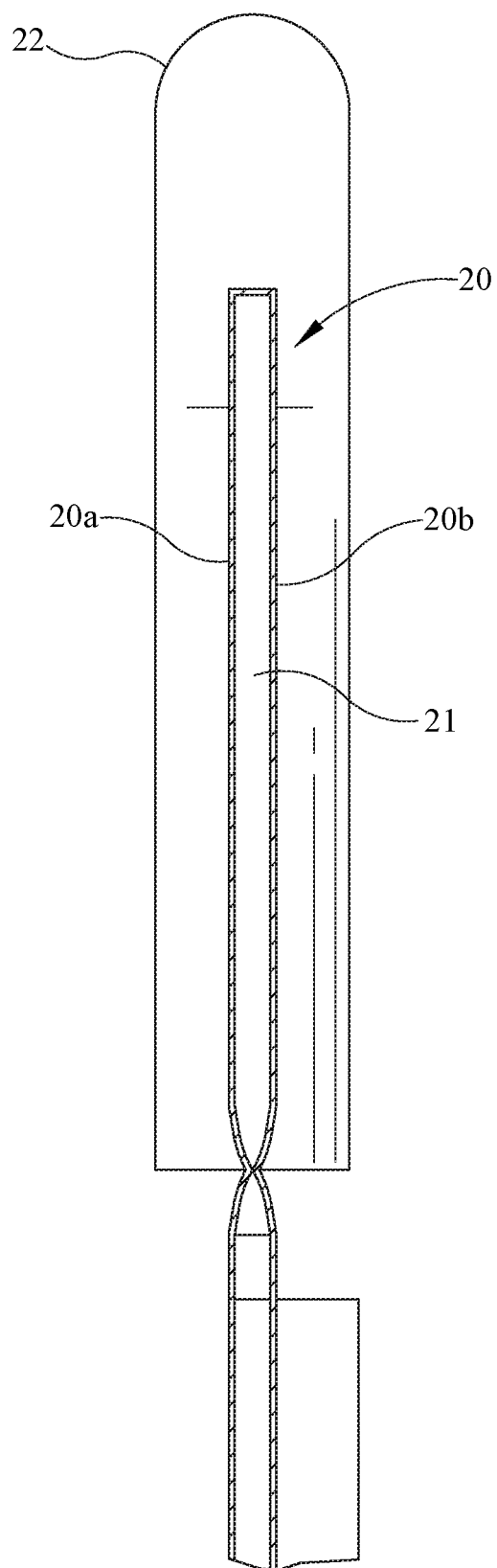


FIG. 6

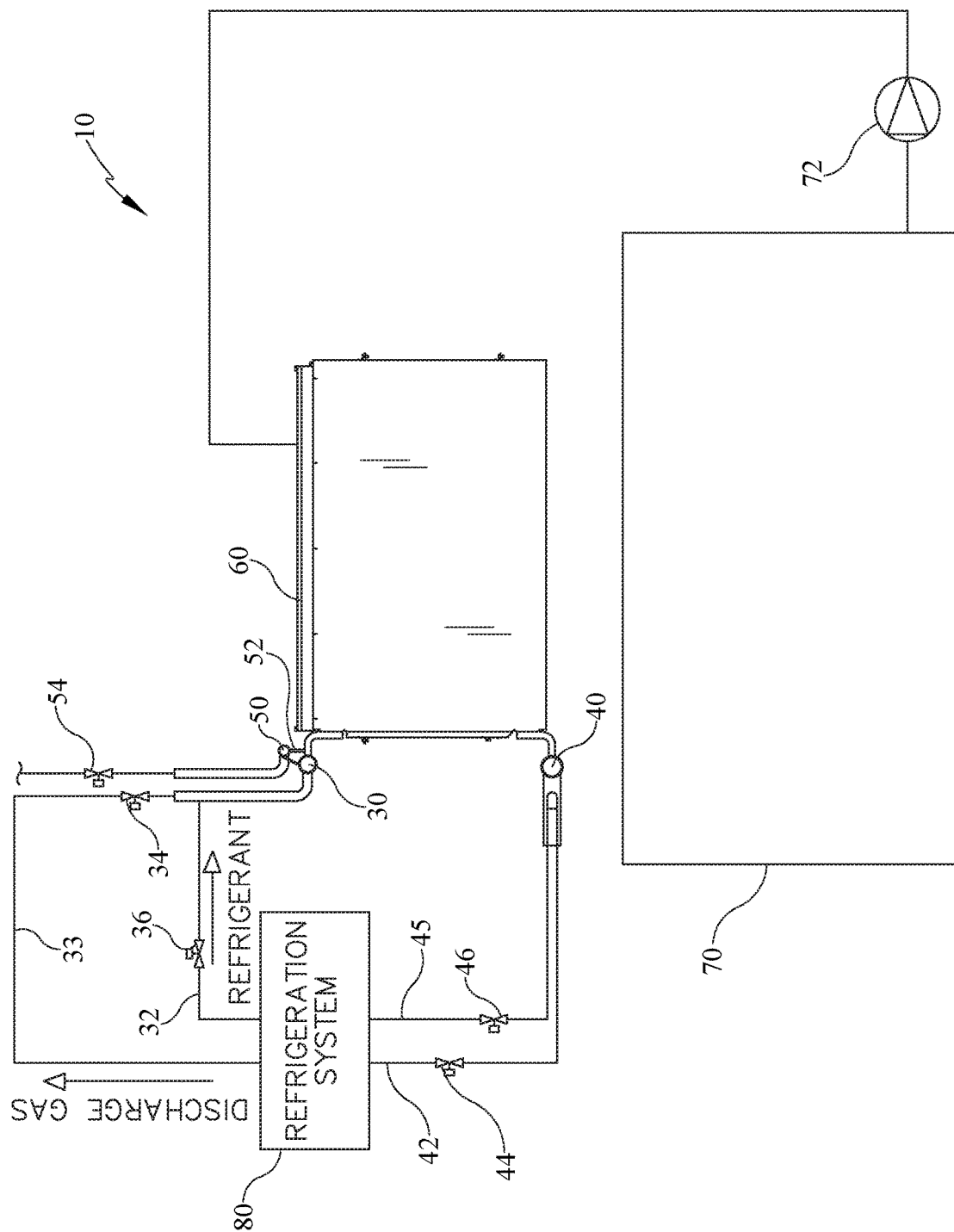


FIG. 7

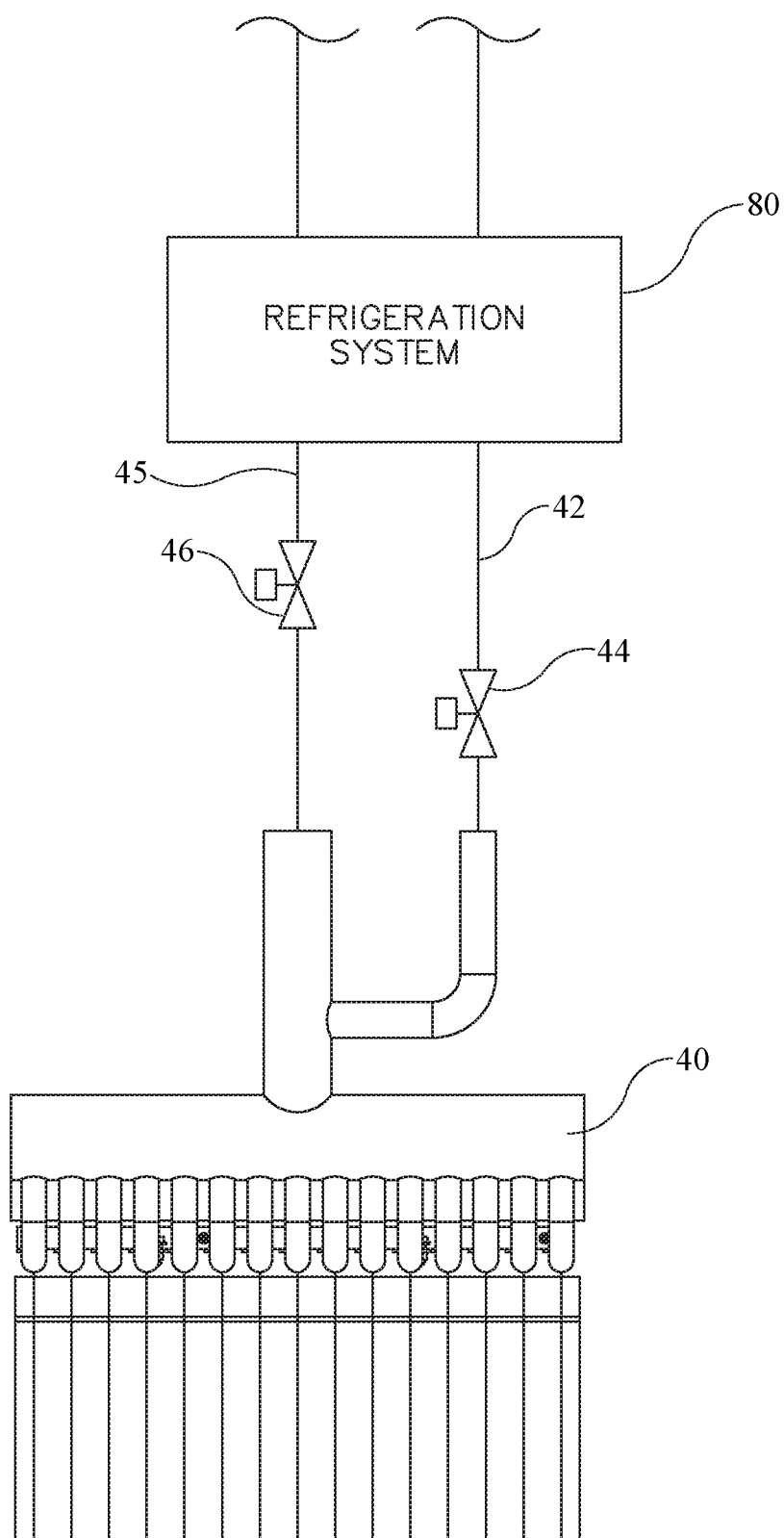


FIG. 8

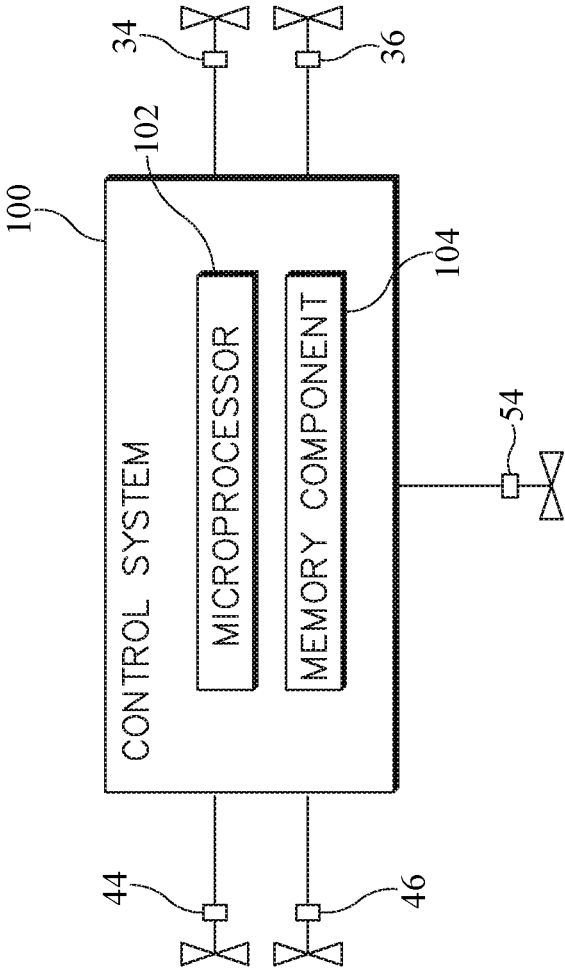


FIG. 9

ICE MACHINE FOR AN ICE-BASED THERMAL STORAGE SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to U.S. Patent Application Ser. No. 62/881,699 filed on Aug. 1, 2019, the entire disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] Ice-based thermal energy storage (TES) has been used for many years as a means of providing cooling effect to an entity, process, building, district, or region, at a reduced overall utility cost to the consumer. Most commonly, ice-based thermal energy storage has been used for Turbine Inlet Air Cooling Thermal Energy Storage (TES-TIAC) at power generation plants or for building and district cooling.

[0003] In a TESTIAC application, a large quantity of ice is produced during period of low demand loads at a power generation plant. The ice is accumulated and stored in ice-water baths in large holding tanks. The ice-water bath is then recirculated in part of a chilled water loop that is directed through a coil at the air inlet of the turbines at the power generation plant. As the turbine draws air across the coil, the temperature and humidity of the air is reduced significantly. This increases the density of the air to the turbine and increases the power output of the turbine. In some cases, the power increase can be as high as ten percent (10%). Power generation plants may use the additional power to handle peak loads or to increase profitability of the plant during certain periods.

[0004] In a building or district cooling application, a locality operates an ice maker during off-peak utility rate hours to produce an ice-water bath, which is then circulated throughout the HVAC system during peak utility demand hours to reduce the utility bill paid by the locality. Such an arrangement has the additional benefit of reducing demand on the power grid during peak hours. Alternately, the TES system can be operated as an ice maker in off-peak hours and a water chiller during peak hours in order to level out the demand that the locality places on the power generation plant throughout the day.

[0005] Historically, both applications are based on the consumption of traditional energy products such as coal, oil, or natural gas at the power generation facility. As technology for renewable energy sources, such as wind and solar, progresses and becomes more efficient, there is a need for improved TES systems, including applications of TES concepts to the use of renewable energy sources.

SUMMARY OF THE INVENTION

[0006] The present invention is an ice machine for an ice-based thermal storage system.

[0007] An ice machine made in accordance with this present invention is configured for use both as a refrigerant evaporator and as a refrigerant condenser (or gas cooler) in the same unit. Specifically, an exemplary ice machine made in accordance with the present invention employs a plurality of pillow plates arranged into a plate bank. Ice is periodically produced on the pillow plates and is then discharged from the pillow plates into a tank of water placed beneath the

plate bank. As ice is created and discharged from the pillow plates, an ice-water bath forms in the tank. Thus, as a refrigerant evaporator, the machine is an ice maker.

[0008] After the ice-water bath in the tank has been formed to the satisfaction of the requirements of the application, the pillow plates accept hot discharge gas (i.e., a hot gaseous refrigerant) and transforms from a refrigerant evaporator to a refrigerant condenser (or gas cooler). As water is recirculated from the ice-water bath in the tank, the water loop gradually heats up and melts the ice. Thus, as a condenser, the machine is an ice melter.

[0009] An exemplary ice machine made in accordance with the present invention includes a plurality of vertically oriented pillow plates, which are arranged in a set that is often referred to as a plate bank. Each of the pillow plates is comprised of two side walls (or panels) that are joined (i.e., welded) together and define an internal cavity therebetween, defining a pathway for the flow of a refrigerant. Furthermore, each pillow plate includes an inlet connection and an outlet connection. Of course, each of the inlet connection and the outlet connection defines a pathway into the internal cavity defined by the pillow plate. All of the inlet connections for the pillow plates are operably connected to a single (or common) header for the purpose of feeding a liquid refrigerant (or a hot discharge gas) into the respective pillow plates, which may be referred to as the feed header. All of the outlet connections for the pillow plates are also operably connected to a single (or common) header for the purpose of drawing a two-phase or gaseous refrigerant (or a condensed liquid or a cooled superheated gas) from the respective plates, which may be referred to as the suction header. Thus, the feed header and the suction header are in fluid communication with one another via the internal cavities defined by the respective pillow plates.

[0010] In the exemplary ice machine, each of the inlet connections for the pillow plates contains a small branch connection to feed warm gas into the internal cavity defined by each pillow plate. At predetermined time intervals, warm gas is introduced into the respective internal cavities of the pillow plates via the respective branch connection, causing accumulated ice to break away and fall from the plates. All of the branch connections for the pillow plates are also operably connected to a single (common) header, which may be referred to as the defrost gas header.

[0011] In the exemplary ice machine, a water distribution pan is positioned at the top of the plate bank. The water distribution pan include multiple openings, such that water received in the water distribution pan is distributed over both sides of each of the pillow plates. Any residual water that does not freeze as it moves down the pillow plates falls off the bottom of the pillow plates. Water that falls off the bottom of the pillow plates is received in a tank positioned beneath the plate bank. A pump is then used to recirculate water back to the water distribution pan.

[0012] In use, as an evaporator, a refrigerant is supplied from a refrigeration system to the feed header of the ice machine, and then is introduced into the internal cavities defined by the respective pillow plates of the plate bank. As the refrigerant passes through each pillow plate, the water distribution pan distributes a film of water over both sides of each pillow plate, covering both sides of each pillow plate. As the relatively warm water comes into thermal contact with the relatively cold refrigerant, heat is transferred from the water, through the side walls of each pillow plate, and

into the refrigerant. This causes the refrigerant to boil and transition from a liquid state to a two-phase or gaseous state, while the water freezes into a layer of ice on both sides of the pillow plate. Any residual water that does not freeze as it moves down the pillow plates falls off the bottom of the pillow plates and into the tank, and then is recirculated back to the water distribution pan.

[0013] After passing through the internal cavities defined by the respective pillow plates of the plate bank, the refrigerant then exits via the suction header as a two-phase or gaseous fluid and is returned to the refrigeration system.

[0014] At predetermined time intervals (which can be established and adjusted by the operator), a small quantity of warm gas is fed via the defrost gas header into the internal cavities defined by the respective pillow plates, causing the internal temperature of the pillow plates to rise. This will melt a thin layer of the ice sheet at the contact surface between the ice sheet and a pillow plate, causing the ice sheet to release from the pillow plate and fall into the tank positioned beneath the plate bank. This completes one ice-making cycle. The ice-making cycles continue until the tank has built up a sufficient amount of ice to handle the desired cooling load determined by the location of installation. For example, an installation may require 200 tons of ice to be generated in a 8-hour time period.

[0015] After a determined quantity of ice has been produced, the ice machine is then able to function as a refrigerant condenser or gas cooler. Hot discharge gas (i.e., a hot gaseous refrigerant) from the compressor of the refrigeration system is supplied to the feed header, and then is introduced into the internal cavities defined by the respective pillow plates of the plate bank. As the hot gaseous refrigerant passes through each pillow plate, the water distribution pan again distributes a film of water over both sides of each pillow plate, covering both sides of each pillow plate. As the now cold water comes into thermal contact with the hot gaseous refrigerant, heat is transferred from the refrigerant, through the side walls of each pillow plate and into the water, causing the gaseous refrigerant to condense into a liquid refrigerant. As a gas cooler, the gaseous refrigerant cools to a lower superheated condition. This action also causes the temperature of the water to rise, falling off of the pillow plates as a warm liquid into the tank beneath the plate bank. This warm water comes into contact with the ice in the tank, causing it to melt. The water is then recirculated back to the water distribution pan at the top of the plate bank, creating a process that continuously warms the water in the tank and melts the ice. After the ice is melted, the water temperature in the tank will continue to rise until all thermal energy has been exhausted.

[0016] After passing through the internal cavities defined by the respective pillow plates of the plate bank, the refrigerant exits via the suction header as a condensed liquid or as a cooled superheated gas and is returned to the refrigeration system.

[0017] The ice machine of the present invention can thus be operably connected directly to and between the refrigerant inlet and outlet of a power generation plant, such as a renewable energy source power generation plant. There is no need for an additional (intermediate) heat exchanger to transfer the heat from the gaseous refrigerant from the power generation plant to the water tank in order to melt the ice, as

the ice machine of the present invention is configured for use both as a refrigerant evaporator and as a refrigerant condenser (or gas cooler).

DESCRIPTION OF THE DRAWINGS

[0018] FIG. 1 is a perspective view of an exemplary ice machine made in accordance with the present invention;

[0019] FIG. 2 is a front view of the exemplary ice machine of FIG. 1;

[0020] FIG. 3 is a side view of the exemplary ice machine of FIG. 1;

[0021] FIG. 4 is a perspective view of one of the pillow plates of the exemplary ice machine of FIG. 1;

[0022] FIG. 5 is a side view of the pillow plate of FIG. 4;

[0023] FIG. 6 is a sectional view of the pillow plate of FIG. 4 taken along line 6-6 of FIG. 5;

[0024] FIG. 7 is a schematic view that shows the incorporation of the exemplary ice machine of FIG. 1 into an ice-based thermal energy storage (TES) system, which can be used for both evaporating and condensing (or gas cooling);

[0025] FIG. 8 is a partial bottom view of the of the exemplary ice machine of FIG. 2, illustrating certain details of the suction header; and

[0026] FIG. 9 is a block diagram that illustrates a control system for the exemplary ice machine of FIGS. 1-8.

DETAILED DESCRIPTION OF THE INVENTION

[0027] The present invention is an ice machine for an ice-based thermal storage system.

[0028] Electricity demands on a power generation grid are naturally fluid. During hot seasons, power demand will be higher in the naturally warmer parts of the day and lower in the naturally cooler parts of the evening and night. For solar power, the energy can only be collected when the sun is shining on the solar panels, but the power demand will exist on cloudy days or at night, when the solar panels are unable to function. Demand fluctuations on the grid will not always match the available power source in this case.

[0029] An ice-based TES system could be deployed to use the collected renewable energy to create an ice-water bath during peak power generation periods, and then, it could be used to offset the needed cooling loads for a building or district on days where solar power generation is less efficient. The load-levelling capability of an ice-based TES system could stabilize the load from a renewable energy grid that may be dependent on traditional batteries for charging and discharging of stored solar and wind energy.

[0030] Furthermore, some renewable energy power generation concepts call for the use of ice as one element of a type of thermal battery, where the energy collected from the solar, wind, or other renewable source is stored during the day and converted back to usable electricity for homes as residents return after the end of the working day. In this configuration, the power generation plant collects renewable energy to power machinery that circulates carbon dioxide as a refrigerant (R744) to produce ice on the low side of the system (as an evaporator) to be used for district cooling and to produce hot water storage tanks (as a condenser) on the high side of the system to be used for district heating. Both the ice and the hot water hold the collected renewable energy to be distributed out to the grid as electricity on demand.

When the energy needs to be distributed, the system operates in reverse, using the stored hot water to drive the refrigeration process to turn electric generators for power consumers. When operated this way, the hot water side becomes the evaporator, and the ice storage side becomes the condenser.

[0031] An ice machine made in accordance with this present invention is thus configured for use both as a refrigerant evaporator and as a refrigerant condenser (or gas cooler) in the same unit. Specifically, an exemplary ice machine made in accordance with the present invention employs a plurality of pillow plates arranged into a plate bank. Ice is periodically produced on the pillow plates and is then discharged from the pillow plates into a tank of water placed beneath the plate bank. As ice is created and discharged from the pillow plates, an ice-water bath forms in the tank. Thus, as a refrigerant evaporator, the machine is an ice maker.

[0032] After the ice-water bath in the tank has been formed to the satisfaction of the requirements of the application, the pillow plates accept hot discharge gas (i.e., a hot gaseous refrigerant) and transforms from a refrigerant evaporator to a refrigerant condenser (or gas cooler). As water is recirculated from the ice-water bath in the tank, the water loop gradually heats up and melts the ice. Thus, as a condenser, the machine is an ice melter.

[0033] Referring now to FIGS. 1-3, an exemplary ice machine 10 made in accordance with the present invention includes a plurality of vertically oriented pillow plates 20, which are arranged in a set that is often referred to as a plate bank (which is generally indicated by reference number 12). In this exemplary embodiment, each plate bank 12 includes fifteen (15) plates at a centerline spacing of approximately 2.50".

[0034] Referring now to FIGS. 4-6, as is common in the construction of plate-based ice machines, each of the pillow plates 20 is comprised of two side walls (or panels) 20a, 20b that are joined (i.e., welded) together and define an internal cavity 21 therebetween, defining a pathway for the flow of a refrigerant. In some embodiments, the side walls 20a, 20b may be joined (i.e., welded) to define specific pathway for the flow of the refrigerant, such as the serpentine pattern shown in FIGS. 4-5. Furthermore, each pillow plate 20 includes an inlet connection 22 and an outlet connection 24. Of course, each of the inlet connection 22 and the outlet connection 24 defines a pathway into the internal cavity 21 defined by the pillow plate 20. In this exemplary embodiment, the inlet connection 22 is at the top of the pillow plate 20, and the outlet connection 24 is at the bottom of the pillow plate 20, making the machine a top-feed design. However, it is possible to switch the position of the inlet connection 22 and the outlet connection 24, thus creating a bottom-feed design, without departing from the spirit and scope of the present invention. The inlet and outlet connections 22, 24 are commonly made of a pipe or tube that extends outward from a vertical edge of the pillow plate 20, running parallel to the length of the pillow plate 20. Alternatively, the inlet and outlet connections 22, 24 may extend upward from the vertical edge of the pillow plate 20, running parallel to the height of the pillow plate 20.

[0035] Referring again to FIGS. 1-3, in this exemplary embodiment, all of the inlet connections 22 for the pillow plates 20 are operably connected to a single (or common) header for the purpose of feeding a liquid refrigerant (or a

hot discharge gas) into the respective pillow plates 20, as further described below. This header may be referred to as the feed header 30.

[0036] Referring still to FIGS. 1-3, in this exemplary embodiment, all of the outlet connections 24 for the pillow plates 20 are also operably connected to a single (or common) header for the purpose of drawing a two-phase or gaseous refrigerant (or a condensed liquid or a cooled superheated gas) from the respective pillow plates 20, as further described below. This header may be referred to as the suction header 40. Of course, the feed header 30 and the suction header 40 are in fluid communication with one another via the internal cavities 21 defined by the respective pillow plates 20.

[0037] Referring still to FIGS. 1-3, each of the inlet connections 22 for the pillow plates 20 contains a small branch connection 52 to feed warm gas into the internal cavity 21 defined by each pillow plate 20 (FIG. 6). At predetermined time intervals, warm gas is introduced into the respective internal cavities of the pillow plates 20 via the respective branch connection 52, causing accumulated ice to break away and fall from the pillow plates 20, as further described below. All of the branch connections 52 for the pillow plates 20 are also operably connected to a single (common) header. This header may be referred to as the defrost gas header 50.

[0038] Referring still to FIGS. 1-3, a water distribution pan 60 is positioned at the top of the plate bank 12, extending the length and the width of the plate bank 12. The water distribution pan 60 include multiple openings 62, such that water received in the water distribution pan 60 is distributed over both sides of each of the pillow plates 20. Any residual water that does not freeze as it moves down the pillow plates 20 falls off the bottom of the pillow plates 20.

[0039] Referring now to FIG. 7, in this exemplary embodiment, water that falls off the bottom of the pillow plates 20 is received in a tank 70 positioned beneath the plate bank 12. A pump 72 is then used to recirculate water back to the water distribution pan 60.

[0040] The ice machine 10 is thus configured for use both as an evaporator and as a condenser (or gas cooler). As an evaporator, the machine is an ice maker. As a condenser (or gas cooler), the machine is an ice melter.

[0041] In use, as an evaporator, a refrigerant is supplied from a refrigeration system to the feed header 30, and then is introduced into the internal cavities defined by the respective pillow plates 20 of the plate bank 12. In this exemplary embodiment, a line 32 connects the refrigeration system 80 to the feed header 30, delivering the refrigerant to the feed header 30. Thus, the line 32 is sized for the liquid feed requirements of the refrigeration system 80 during the ice-making cycle. (Sizing is based on standard refrigeration piping charts that are well-known to those skilled in the art.) An isolation valve 36 is installed in the line 32 and interposed between the refrigeration system 80 and the feed header 30, which is open during the ice-making cycle and closed during the ice-melting cycle (described below). In any event, as the refrigerant passes through each pillow plate 20, the water distribution pan 60 distributes a film of water over both sides of each pillow plate 20, covering both sides of each pillow plate 20. As the relatively warm water comes into thermal contact with the relatively cold refrigerant, heat is transferred from the water, through the side walls 20a, 20b of each pillow plate 20, and into the refrigerant. This causes

the refrigerant to boil and transition from a liquid state to a two-phase or gaseous state, while the water freezes into a layer of ice on both sides of the pillow plate 20. Any residual water that does not freeze as it moves down the pillow plates 20 falls off the bottom of the pillow plates 20 and into the tank 70, and then is recirculated back to the water distribution pan 60. In this regard, the water is moving between the plate bank 12 and the tank 70 in a closed-loop circuit. This causes the recirculating water coming back to the water distribution pan 60 to be at a temperature very near to the freezing point, the importance of which is further described below.

[0042] After passing through the internal cavities defined by the respective pillow plates 20 of the plate bank 12, the refrigerant then exits via the suction header 40 as a two-phase or gaseous fluid and is returned to the refrigeration system 80. In this exemplary embodiment, a line 45 connects the suction header 40 to the refrigeration system 80, returning the refrigerant to the refrigeration system 80. An isolation valve 46 is installed in the line 45 and interposed between the suction header 40 and the refrigeration system 80, which is open during the ice-making cycle and closed during the ice-melting cycle (described below).

[0043] At predetermined time intervals, a small quantity of warm gas is fed via the defrost gas header 50 into the internal cavities defined by the respective pillow plates 20, causing the internal temperature of the pillow plates 20 to rise. This will melt a thin layer of the ice sheet at the contact surface between the ice sheet and a pillow plate 20, causing the ice sheet to release from the pillow plate 20 and fall into the tank 70 positioned beneath the plate bank 12. This completes one ice-making cycle. With respect to the thickness of the ice, it can often range from about 0.125" thick to 1.00" thick, and, in most cases, is about 0.25" to 0.375" thick.

[0044] Referring again to FIG. 7, in this exemplary embodiment, the ice sheets also fall into and float in the tank 70, thus further reducing the temperature of the closed-loop water circuit and improving the efficiency of the ice-making process. In this regard, repeated ice-making cycles will cause freshly produced ice sheets to collide with previously produced ice sheets, breaking them into pieces of ice in the tank 70. The ice-making cycles continue until the tank 70 has built up a sufficient amount of ice to handle the desired cooling load determined by the location of installation. The tank 70 thus begins the ice-making process as being full of only water. By the end of the ice-making process, the tank 70 is mostly full of ice, leaving some water to be recirculated.

[0045] After a predetermined quantity of ice has been produced, the ice machine 10 is then able to function as a refrigerant condenser or gas cooler. In this exemplary embodiment, hot discharge gas (i.e., a hot gaseous refrigerant) from the compressor of the refrigeration system 80 is supplied to the feed header 30, and then is introduced into the internal cavities defined by the respective pillow plates 20 of the plate bank 12. In this exemplary embodiment, a line 33 connects the compressor of the refrigeration system 80 to the feed header 30, delivering the hot gaseous refrigerant to the feed header 30. An isolation valve 34 is installed in the line 33 and interposed between the refrigeration system 80 and the feed header 30, which is open during the ice-melting cycle and closed during the ice-making cycle (described above). In any event, as the hot gaseous refrigerant

passes through each pillow plate 20, the water distribution pan 60 again distributes a film of water over both sides of each pillow plate 20, covering both sides of each pillow plate 20. As the now cold water comes into thermal contact with the hot gaseous refrigerant, heat is transferred from the refrigerant, through the side walls 20a, 20b of each pillow plate 20 and into the water, causing the gaseous refrigerant to condense into a liquid refrigerant. As a gas cooler, the hot gaseous refrigerant cools to a lower superheated condition. This action also causes the temperature of the water to rise, falling off of the pillow plates 20 as a warm liquid into the tank 70 beneath the plate bank 12. This warm water comes into contact with the ice in the tank 70, causing it to melt. The pump 72 then recirculates the water back to the water distribution pan 60 at the top of the plate bank 12, creating a process that continuously warms the water in the tank 70 and melts the ice. After the ice is melted, the water temperature in the tank 70 will continue to rise until all thermal energy has been exhausted.

[0046] After passing through the internal cavities 21 defined by the respective pillow plates 20 of the plate bank 12, the refrigerant exits via the suction header 40 as a condensed liquid or as a cooled superheated gas and is returned to the refrigeration system 80. In this exemplary embodiment, a line 42 connects the suction header 40 to the refrigeration system 80, returning hot discharge gas to the refrigeration system 80. An isolation valve 44 is installed in the line 42 and interposed between the suction header 40 and the refrigeration system 80, which is closed during the ice-making cycle and open during the ice-melting cycle (described above).

[0047] Referring still to FIG. 7, the size of the feed header 30 is determined by the hot discharge gas requirements of the refrigeration system during the ice-melting cycle with reference to standard refrigeration piping charts that are well-known to those skilled in the art.

[0048] Referring now to FIG. 8, the size of the suction header 40 is determined by the suction requirements of the refrigeration system during the ice-making cycle with reference to standard refrigeration piping charts that are well-known to those skilled in the art.

[0049] Referring again to FIG. 7, the size of the defrost gas header 50 is determined by the warm gaseous refrigerant requirements of the plate bank 12 during the ice-making cycle. Specifically, the size is based on the size of the pillow plates 20, the number of pillow plates 20 in the plate bank 12, and the time limits for releasing the ice sheets from the pillow plates 20. An isolation valve 54 periodically opens and closes during the ice-making cycle to feed warm gas via the defrost gas header 50 into the internal cavities defined by the respective pillow plates 20, which, as described above, releases the ice sheets from the pillow plates 20 in the plate bank 12. The valve 54 is closed during the entire ice-melting cycle.

[0050] The ice machine of the present invention can thus be operably connected directly to and between the refrigerant inlet and outlet of a power generation plant, such as a renewable energy source power generation plant. There is no need for an additional (intermediate) heat exchanger to transfer the heat from the gaseous refrigerant from the power generation plant to the water tank in order to melt the ice, as the ice machine of the present invention is configured for use both as a refrigerant evaporator and as a refrigerant condenser (or gas cooler).

[0051] FIG. 9 is a block diagram that illustrates a control system 100 for the exemplary ice machine of FIGS. 1-8. As shown, such a control system 100 includes a microprocessor 102 and a memory component 104. Each of the valves 34, 36, 44, 46, 54 is operably connected to and receives control signals from the control system 100 to open or close each of the valves 34, 36, 44, 46, 54 at the appropriate time. Such control signals could be communicated in response to operator input or as part of the execution of a preprogrammed routine stored in the memory component 104.

[0052] Referring still to FIG. 9, as described above, during the ice-making cycle, the valve 36 between the refrigeration system 80 and the feed header 30 is open, thus allowing the refrigerant from the refrigeration system 80 to flow to the feed header 30, while the valve 34 is closed. During the ice-melting cycle, the valve 36 is closed, while the valve 34 between the refrigeration system 80 and the feed header 30 is open, thus allowing the hot discharge gas (i.e., a hot gaseous refrigerant) from the refrigeration system 80 to flow to the feed header 30. Similarly, as also described above, during the ice-making cycle, the valve 46 between the suction header 40 and the refrigeration system 80 is open, while the valve 44 is closed. During the ice-melting cycle, the valve 44 between the suction header 40 and the refrigeration system 80 is open, while the valve 46 is closed.

[0053] Referring still to FIG. 9, as also described above, the valve 54 is periodically opened during the ice-making cycle to feed warm gas via the defrost gas header 50 into the internal cavities defined by the respective pillow plates 20, which, as described above, releases the ice sheets from the pillow plates 20 in the plate bank 12. The valve 54 is closed during the entire ice-melting cycle.

[0054] One of ordinary skill in the art will also recognize that additional embodiments and implementations are also possible without departing from the teachings of the present invention. This detailed description, and particularly the specific details of the exemplary embodiment disclosed therein, is given primarily for clarity of understanding, and no unnecessary limitations are to be understood therefrom, for modifications will become obvious to those skilled in the art upon reading this disclosure and may be made without departing from the spirit or scope of the present invention.

What is claimed is:

1. An ice machine for an ice-based thermal storage system, comprising:

a plurality of pillow plates arranged in a plate bank, wherein each of the plurality of pillow plates includes an inlet connection and an outlet connection, with the respective inlet connections connected to a feed header, and with the respective outlet connections connected to a suction header;

a water distribution pan positioned at a top of the plate bank; and

a tank positioned below the plate bank;

wherein the ice machine is configured for use both as an evaporator and as a condenser.

2. The ice machine as recited in claim 1, wherein, in use as the evaporator, a refrigerant is received by the feed header via a first line connecting a refrigeration system to the feed header, is introduced into the plurality of pillow plates, and then exits via the suction header, such that heat from water distributed from the water distribution pan over the plurality of pillow plates is transferred to the refrigerant, thus forming

ice on the plurality of pillow plates, which then falls into the tank positioned below the plate bank.

3. The ice machine as recited in claim 2, wherein, in use as the condenser, a hot gaseous refrigerant is received by the feed header via a second line connecting the refrigeration system to the feed header, is introduced into the plurality of pillow plates, and then exits via the suction header, such that heat from the hot gaseous refrigerant is transferred to water distributed from the water distribution pan over the plurality of pillow plates, such that water at an increased temperature falls into the tank positioned below the plate bank.

4. The ice machine as recited in claim 3, and further comprising:

a first valve installed in the first line, which is open when the ice machine is in use as the evaporator, thus allowing the refrigerant to flow into the feed header, and is closed when the ice machine is in use as the condenser; and

a second valve installed in the second line, which is open when the ice machine is in use as the condenser, thus allowing the hot gaseous refrigerant to flow into the feed header, and is closed when the ice machine is in use as the condenser.

5. The ice machine as recited in claim 4, and further comprising a control system that is operably connected to and communicates control signals to the first valve and the second valve.

6. The ice machine as recited in claim 1, and further comprising a pump configured to recirculate water from the tank to the water distribution pan.

7. The ice machine as recited in claim 1, each of the plurality of pillow plates is comprised of two side walls that are joined together and define an internal cavity.

8. The ice machine as recited in claim 2, wherein the refrigerant is received from the refrigeration system of a power generation plant.

9. The ice machine as recited in claim 3, wherein the hot gaseous refrigerant is received from the refrigeration system of a power generation plant.

10. The ice machine as recited in claim 1, wherein the inlet connection of each of the plurality of pillow plates includes a branch connection configured to feed warm gas into the pillow plate at predetermined time intervals.

11. An ice machine for an ice-based thermal storage system, comprising:

a plurality of pillow plates arranged in a plate bank, wherein each of the plurality of pillow plates is comprised of two side walls that are joined together and define an internal cavity, and wherein each of the plurality of pillow plates includes an inlet connection and an outlet connection, with the respective inlet connections connected to a feed header, and with the respective outlet connections connected to a suction header;

a water distribution pan positioned at a top of the plate bank and configured to distribute water over the respective side walls of each of the plurality of pillow plates; and

a tank positioned below the plate bank;

wherein, in use as an evaporator, a refrigerant is received by the feed header, is introduced into the respective internal cavities defined by the plurality of pillow plates, and then exits via the suction header, such that heat from water distributed from the water distribution

pan over the respective side walls of each of the plurality of pillow plates is transferred to the refrigerant, thus forming ice on respective side walls of each of the plurality of pillow plates, which then falls into the tank positioned below the plate bank; and wherein, in use as a condenser, a hot gaseous refrigerant is received by the feed header, is introduced into the respective internal cavities defined by the plurality of pillow plates, and then exits via the suction header, such that heat from the hot gaseous refrigerant is transferred to water distributed from the water distribution pan over the respective side walls of each of the plurality of pillow plates, such that water at an increased temperature falls into the tank positioned below the plate bank.

12. The ice machine as recited in claim 1, and further comprising:

- a first line delivering the refrigerant to the feed header;
- a first valve installed in the first line, which is open when the ice machine is in use as the evaporator, thus allowing the refrigerant to flow into the feed header, and is closed when the ice machine is in use as the condenser;
- a second line delivering the hot gaseous refrigerant to the feed header; and
- a second valve installed in the second line, which is open when the ice machine is in use as the condenser, thus allowing the hot gaseous refrigerant to flow into the feed header, and is closed when the ice machine is in use as the condenser.

13. The ice machine as recited in claim 12, and further comprising a control system that is operably connected to and communicates control signals to the first valve and the second valve.

14. The ice machine as recited in claim 11, and further comprising a pump configured to recirculate water from the tank to the water distribution pan.

15. A thermal storage system, comprising:

an ice machine, including

- a plurality of pillow plates arranged in a plate bank, wherein each of the plurality of pillow plates is comprised of two side walls that are joined together and define an internal cavity, and wherein each of the plurality of pillow plates includes an inlet connection and an outlet connection, with the respective inlet connections connected to a feed header, and with the respective outlet connections connected to a suction header,
- a water distribution pan positioned at a top of the plate bank and configured to distribute water over the respective side walls of each of the plurality of pillow plates, and
- a tank positioned below the plate bank;
- a refrigeration system, which is in fluid communication with the feed header of the ice machine, and in is fluid communication with the suction header of the ice machine;

wherein, in a first configuration, a refrigerant is supplied by the refrigeration system to the feed header, is introduced into the respective internal cavities defined by the plurality of pillow plates, and then exits via the suction header, such that heat from water distributed from the water distribution pan over the respective side walls of each of the plurality of pillow plates is trans-

ferred to the refrigerant, thus forming ice on respective side walls of each of the plurality of pillow plates, which then falls into the tank positioned below the plate bank; and

wherein, in a second configuration, a hot gaseous refrigerant is supplied by the refrigeration system to the feed header, is introduced into the respective internal cavities defined by the plurality of pillow plates, and then exits via the suction header, such that heat from the hot gaseous refrigerant is transferred to water distributed from the water distribution pan over the respective side walls of each of the plurality of pillow plates, such that water at an increased temperature falls into the tank positioned below the plate bank.

16. The thermal storage system as recited in claim 15, and further comprising:

- a first line connecting the refrigeration system to the feed header, delivering the refrigerant to the feed header;
- a first valve installed in the first line and positioned between the refrigeration system and the feed header, which is open in the first configuration, thus allowing the refrigerant from the refrigeration system to flow to the feed header, and is closed in the second configuration;
- a second line connecting the refrigeration system to the feed header, delivering the hot gaseous refrigerant to the feed header; and
- a second valve installed in the second line and positioned between the refrigeration system and the feed header, which is open in the second configuration, thus allowing the hot gaseous refrigerant from the refrigeration system to flow to the feed header, and is closed in the first configuration.

17. The thermal storage system as recited in claim 16, and further comprising:

- a third line connecting the suction header to the refrigeration system, returning the refrigerant to the refrigeration system as a two-phase or gaseous fluid;
- a third valve installed in the third line and positioned between the suction header and the refrigeration system, which is open in the first configuration, thus allowing the refrigerant to return to the refrigeration system, and is closed in the second configuration;
- a fourth line connecting the suction header to the refrigeration system, returning the hot gaseous refrigerant to the refrigeration system; and
- a fourth valve installed in the fourth line and positioned between the suction header and the refrigeration system, which is open in the second configuration, thus allowing the hot gaseous refrigerant from the refrigeration system to return to the refrigeration system, and is closed in the first configuration.

18. The thermal storage system as recited in claim 16, and further comprising a control system that is operably connected to and communicates control signals to the first valve and the second valve.

19. The thermal storage system as recited in claim 17, and further comprising a control system that is operably connected to and communicates control signals to each of the first valve, the second valve, the third valve, and the fourth valve.

20. The thermal storage system as recited in claim 15, and further comprising a pump configured to recirculate water from the tank to the water distribution pan.

21. The thermal storage system as recited in claim **15**, wherein the refrigeration system is associated with a power generation plant.

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