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# (54) METHODS AND SYSTEMS OF COOLING PROCESS PLANT WATER

VERFAHREN UND SYSTEME ZUR KÜHLUNG VON PROZESSANLAGENWASSER

PROCÉDÉS ET SYSTÈMES DE REFROIDISSEMENT D'EAU D'INSTALLATION DE TRAITEMENT

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## Description

## BACKGROUND

**[0001]** This invention relates to methods and systems for cooling process plant water.

**[0002]** Petrochemical processing plants, such as those involved in the processing of natural gas and olefins and the generation of syngas, can include refrigeration systems that use water-based coolants, also referred to as process plant water, for cooling components of the processing plant. For example, certain water-based cooling systems can be used to remove heat from reactions performed in a processing plant and for the separation of substances within hydrocarbon mixtures for use in a processing plant. Water-based cooling systems can also be used for the condensation of hydrocarbon gas streams.

**[0003]** Document EP 2 426 433 A2, for example, discloses a system for cooling an external load, the system comprising a heat exchanging system for exchanging heat between a refrigerant of a refrigerant circuit and process water circulating in two separated process water circuits. The refrigerant circuit comprises a two-stage centrifugal compressor, a vapor liquid separator and two expansion valves. Accordingly, document EP 2 426 433 A2 reveals a method for cooling an external load.

**[0004]** Refrigeration methods and systems in the petrochemical industry can use a series of two-stage compressors, flash drums, liquid pumps, cooling towers and heat exchangers, which can lead to high capital and operating costs. Therefore, there remains a need in the art for more efficient and cost-effective methods of cooling process water.

## SUMMARY

**[0005]** The above-mentioned problem is solved by providing a method according to claim 1 for cooling process plant water and a system according to claim 11. Further embodiments of the invention are provided in the appended dependent claims. The system according to claim 11 includes a heat exchange system for exchanging heat between a first process water stream and a second process water stream with a refrigerant, and one or more of a process plant system.

**[0006]** According to the invention a method is provided for cooling process plant water including exchanging heat between a first process water stream and a liquid refrigerant within a first heat exchanger to lower the temperature of the process water stream. The refrigerant is partially vaporized upon the exchange of heat with the first process water stream to generate a partially vaporized refrigerant having a vapor phase and a liquid phase. The method includes increasing the pressure of the partially vaporized refrigerant and transferring at least a portion of the refrigerant to a second heat exchanger.

**[0007]** Furthermore, the method includes exchanging heat between a second process water stream and the partially vaporized refrigerant within the second heat exchanger to decrease the temperature of the refrigerant. The method includes lowering the pressure and/or temperature of the partially vaporized refrigerant portion and transferring the partially vaporized refrigerant portion to a vapor-liquid separator to separate the liquid phase from the vapor phase thereof, thereby generating a liquid refrigerant. The method further includes lowering the temperature of the liquid refrigerant and transferring at least a portion of the refrigerant to the first heat exchanger to exchange heat with the first process water stream. The method includes transferring the cooled process water to one or more process plants. The pressure of the partially vaporized refrigerant is increased in a multiphase pump.

**[0008]** In certain embodiments, the vapor-liquid separator can be a flash drum. In certain embodiments, the liquid refrigerant includes a refrigerant that has a viscosity greater than or equal to about 0.1 cP at a temperature of about 0°C. In certain embodiments, the liquid refrigerant includes a refrigerant that has a boiling point temperature from about -10°C to about -50°C. The liquid refrigerant can be R134A, R404A, R407C, R125 and R410A, and the partially vaporized refrigerant can have a vapor phase of about 30% to about 50%.

**[0009]** The method includes transferring the first process water from the first heat exchanger to one or more process plants, and transferring the partially vaporized refrigerant from the first heat exchanger to a multiphase pump to increase the pressure of the partially vaporized refrigerant. The method includes transferring the partially vaporized refrigerant from the multiphase pump to a second heat exchanger. The method further includes exchanging heat between a second process water stream and the partially vaporized refrigerant within the second heat exchanger to lower the pressure and/or temperature of the refrigerant. The method includes transferring the second process water stream from the second heat exchanger to become the first process water stream entering the first heat exchanger. The method includes transferring the partially vaporized refrigerant from the second heat exchanger to a first expansion valve to lower the pressure and/or temperature of the refrigerant.

**[0010]** The method includes transferring the partially vaporized refrigerant from the first expansion valve to a vapor-liquid separator to separate the liquid phase from the vapor phase thereof, thereby generating a liquid refrigerant. The method includes transferring the liquid refrigerant from the vapor-liquid separator to a second expansion valve to lower the temperature of the liquid refrigerant, and transferring the refrigerant from the second expansion valve to the first heat exchanger to exchange heat with the first process water stream.

**[0011]** In certain embodiments, the refrigerant can be partially vaporized upon the exchange of heat with the first process water stream. The method can include transferring the partially vaporized refrigerant from the first heat exchanger to a vapor-liquid separator to separate the vapor phase from the liquid phase of the refrigerant. The method can include transferring the vapor phase of the refrigerant to a gas compressor for the compression of the refrigerant. The method can include combining the compressed vapor phase of the refrigerant with the liquid phase of the refrigerant to generate a pressurized partially vaporized refrigerant, and exchanging heat between a second process water stream and the refrigerant within a second heat exchanger to lower the temperature of the refrigerant.

**[0012]** In certain embodiments, the method can include transferring the refrigerant from the second heat exchanger to a first expansion valve to lower the pressure and/or temperature of the refrigerant. The method can further include transferring the refrigerant from the first expansion valve to a second vapor-liquid separator to separate the vapor phase from the liquid phase of the refrigerant. In certain embodiments, the method includes transferring the liquid phase of the refrigerant from the second vapor-liquid separator to a second expansion valve to lower the temperature of the liquid refrigerant and transferring the refrigerant from the second expansion valve to the first heat exchanger to exchange heat with the first process water stream. The refrigerant can be partially vaporized to have a liquid fraction of about 98%. In certain embodiments, the method can further include transferring the vapor phase of the refrigerant from the second vapor-liquid separator to the gas compressor.

**[0013]** The disclosed subject matter also provides systems for cooling process plant water that includes a first heat exchanger for exchanging heat between a first process water stream and a refrigerant. The system further includes a multiphase pump, coupled to the first heat exchanger, to increase the pressure of the refrigerant. The system includes a second heat exchanger, coupled to the multiphase pump and the first heat exchanger, for exchanging heat between a second process water stream and the refrigerant. The system includes a first expansion valve, coupled to the second heat exchanger, for lowering the temperature of the refrigerant. The system further includes a vapor-liquid separator, coupled to the first expansion valve and the multiphase pump, for separating the liquid and vapor phases of the refrigerant, and a second expansion valve, coupled to the vapor-liquid separator and the first heat exchanger, for lowering the temperature of the liquid phase of the refrigerant. The vapor-liquid separator can be flash drum.

**[0014]** In certain embodiments, the system can include a first vapor-liquid separator, coupled to the first heat exchanger, to separate the vapor phase from the liquid phase of the refrigerant. The system can further include a pump, coupled to the first vapor-liquid separator, for transferring at least a portion of the liquid phase of the refrigerant. The system can include a gas compressor, coupled to the first vapor-liquid separator, for increasing the pressure of the vapor phase of the refrigerant. It can also include a transfer line, coupled to the gas compressor and the pump, for combining the vapor phase of the refrigerant and the compressed liquid phase of the refrigerant, thereby generating a partially vaporized refrigerant. The system can include a second heat exchanger, coupled to the transfer line and the first heat exchanger, for exchanging heat between a second process water stream and the refrigerant. The system can include a first expansion valve, coupled to the second heat exchanger, for lowering the temperature of the refrigerant, and a second vapor-liquid separator, coupled to the first expansion valve and the gas compressor, for separating the liquid and vapor phases of the refrigerant. The system can include a second expansion valve, coupled to the second vapor-liquid separator and the first heat exchanger, for lowering the temperature of the liquid phase of the refrigerant and transferring the refrigerant to the first heat exchanger. In certain embodiments, the refrigerant being transferred from the second expansion valve to the first heat exchanger has vapor fraction of about 2% and/or a liquid fraction of about 98%.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0015]**

FIG. 1 depicts a method for cooling process plant water according to one exemplary embodiment of the disclosed subject matter.

FIG. 2 depicts a method for cooling process plant water according to one exemplary embodiment of the disclosed subject matter.

FIG. 3 depicts a system for cooling process plant water according to one exemplary embodiment of the disclosed subject matter.

FIG. 4 depicts a system for cooling process plant water according to one exemplary embodiment of the disclosed subject matter.

## DETAILED DESCRIPTION

**[0016]** The disclosed subject matter provides techniques for cooling process plant water. In particular non-limiting embodiments, the presently disclosed subject matter provides closed-loop methods and systems for cooling process plant water. In certain embodiments, the methods and/or systems of the present invention do not include a heat sink, *e.g.*, a cooling tower.

**[0017]** Water-based coolant, *i.e.*, process plant water, can be used to cool industrial plants such as petrochemical plants (also referred to herein as process plants and processing plants). The process plant water can include water from any source, such as but not limited, potable water, demineralized water, ocean water, sea water, ground water, stream water or river water. In certain embodiments, the process plant water can have a pH of about 7 to about 8 and/or an amount less than or equal to about 0.15 mg/kg of dissolved solids. In certain embodiments, such process plant water can be used for the condensation of hydrocarbon gas streams, for the separation of substances within a mixture for use in the process plant and/or for the removal of heat from chemical reactions within the process plant.

**[0018]** For the purpose of illustration and not limitation, FIGS. 1 and 2 are schematic representations of methods according to non-limiting embodiments of the disclosed subject matter. In certain embodiments, the method 100 or 200 includes exchanging heat between a first process water stream and a liquid refrigerant to lower the temperature of, *i.e.*, cool, the first process water stream 101 or 201. Heat exchange between the first process water stream and refrigerant can occur within a first heat exchanger to form a cooled first process water stream.

**[0019]** In certain embodiments, prior to exchanging heat with the refrigerant, the first process water stream can have a temperature from about 35°C to about 40°C. In certain embodiments, the temperature of the first process water stream prior to heat exchange with the refrigerant can be about 38°C. In certain embodiments, after exchanging heat with the refrigerant, the temperature of the first process water stream can be from about 24°C to about 26°C. In certain embodiments, the temperature of the first process water stream can be lowered to a temperature of about 25°C after exchanging heat with the refrigerant.

**[0020]** As used herein, the term "about" or "approximately" means within an acceptable error range for the particular value as determined by one of ordinary skill in the art, which will depend in part on how the value is measured or determined, *i.e.*, the limitations of the measurement system. For example, "about" can mean a range of up to 20%, up to 10%, up to 5% and/or up to 1% of a given value.

**[0021]** The liquid refrigerant for use in the disclosed subject matter can be any refrigerant that has a viscosity equal to or greater than about 0.1 centipoise (cP). In certain embodiments, the refrigerant has a viscosity from about 0.1 cP to about 1.0 cP or from about 0.1 cP to about 0.5 cP. For example, and not by way of example, the refrigerant can have a viscosity from about 0.1 cP to about 0.45 cP, from about 0.1 cP to about 0.4 cP, from about 0.1 cP to about 0.35 cP, from about 0.1 cP to about 0.3 cP, from about 0.1 cP to about 0.25 cP, from about 0.1 cP to about 0.2 cP, from about 0.1 cP to about 0.15 cP, from about 0.15 cP to about 0.50 cP, from about 0.20 cP to about 0.50 cP, from about 0.25 cP to about 0.50 cP, from about 0.30 cP to about 0.50 cP, from about 0.35 cP to about 0.50 cP, from about 0.40 cP to about 0.50 cP or from about 0.45 cP to about 0.5 cP. In certain embodiments, the viscosity of the refrigerant is measured at 0°C.

**[0022]** The refrigerant for use in the disclosed subject matter can have a boiling point temperature of about -10°C to about -50°C. For example, the refrigerant can have a boiling point temperature of about -10°C to about -45°C, about -10°C to about -40°C, about -10°C to about -35°C, about -10°C to about -30°C, about -10°C to about -25°C, about -10°C to about-20°C, about -10°C to about -15°C, about -15°C to about -50°C, about -20°C to about -50°C, about -25°C to about -50°C, about -30°C to about -50°C, about -35°C to about -50°C, about-40°C to about -50°C or about -45°C to about -50°C. Such low boiling point temperatures can allow the refrigerant to evaporate easily and exchange heat rapidly with the process water stream. Non-limiting examples of refrigerants suitable for use in the disclosed subject matter include hydrocarbon-based refrigerants, R134A, R404A, R407C, R125 and R410A.

**[0023]** In certain embodiments, prior to exchanging heat with the first process water stream, the temperature of the refrigerant can be from about 5°C to about 10°C, e.g., about 9°C. In certain embodiments, after exchanging heat with the first process water stream, the temperature of the refrigerant can be from about 7°C to about 20°C.

**[0024]** In certain embodiments, the refrigerant is at least partially vaporized upon the exchange of heat with the first process water stream. "Partially vaporized," as used herein, can mean that more than about 10%, more than about 20%, more than about 30%, more than about 35%, more than about 40%, more than about 45%, more than about 50% or more than about 55% of the refrigerant is vaporized (*i.e.*, is in the vapor phase). In certain embodiments, "partially vaporized" can mean that about 30% to about 40% of the refrigerant is vaporized following the exchanging of heat between the refrigerant and the first process water stream. In certain embodiments, about 40% of the refrigerant is vaporized following the exchanging of heat between the refrigerant and the first process water stream.

**[0025]** The method 100 or 200 can further include transferring the cooled first process water stream, *e.g.*, from the first heat exchanger, to one or more process plants 102 or 202. The process plant can be any plant that uses process water for cooling the one or more reactors and/or gas streams of the process plant. For example, the cooled process water can be transferred to a process plant that produces aromatics, speciality chemicals, olefins, methanol, syngas, etc.

**[0026]** In certain embodiments, and with reference to FIG. 1, the method 100 further includes increasing the pressure of the partially vaporized refrigerant 103 to, for example, generate a pressurized partially vaporized refrigerant. In certain embodiments, the pressure of the partially vaporized refrigerant is increased within a multiphase pump by transferring the partially vaporized refrigerant from the first heat exchanger to the multiphase pump. At least a portion of the partially vaporized refrigerant is transferred from the first heat exchanger to the multiphase pump. As used herein, "at least a portion" can refer to an amount greater than about 40%, greater than about 50%, greater than about 60%, greater than about 70%, greater than about 80%, greater than about 90%, greater than about 95% or greater than about 99%.

**[0027]** In certain embodiments, the pressure of the partially vaporized refrigerant can be increased to a pressure of about 5 bar to about 15 bar, e.g., to about 14 bar. The heat generated by the multiphase pump can increase the temperature and/or increase the percentage of the vapor phase of the partially vaporized refrigerant. After pressurization, the refrigerant can have a vapor fraction of about 55% to about 60%. In certain embodiments, the partially vaporized refrigerant can have a vapor fraction of about 55% after the increase in pressure, *e.g.*, within and/or exiting the multiphase pump. The temperature of the partially vaporized refrigerant can increase to a temperature of about 50°C to about 55°C. In certain embodiments, the temperature of the pressurized partially vaporized refrigerant can increase to a temperature of about 52°C.

**[0028]** Alternatively or additionally, and as depicted in FIG. 2, the method of the disclosed subject matter 200 includes separating the liquid phase from the vapor phase of the partially vaporized refrigerant 203. At least a portion of the liquid phase of the refrigerant is separated from the vapor phase of the refrigerant. The separation of the liquid phase from the vapor phase of the refrigerant occurs by transferring the partially vaporized refrigerant from the first expansion valve to a vapor-liquid separator, *e.g.*, a flash drum. In a vapor-liquid separator, a stream of a liquid/vapor mixture, *e.g.*, a multiphasic refrigerant, can be fed through a throttling valve at the entry point (feed inlet) into the vapor-liquid separator, causing rapid reduction in pressure and partial vaporization (flashing) of the liquid in the stream. Gas can be removed from a gas outlet (vapor outlet) at the top of the vapor-liquid separator while liquid can be removed from a liquid outlet at the bottom of the vapor-liquid separator. The separated vapor phase of the refrigerant can undergo compression, *e.g.*, within a gas compressor, and can be combined with the separated liquid phase to generate a partially vaporized refrigerant 204, *e.g.*, a pressurized partially vaporized refrigerant. The compressed vapor can have a temperature of about 57°C and a pressure of about 14 bar following compression. In certain embodiments, the liquid refrigerant exiting the liquid pump can have a temperature of about 9°C and a pressure of about 14 bar. In certain embodiments, the partially vaporized refrigerant obtained after the mixing of the compressed vapor refrigerant and the liquid refrigerant exiting the liquid pump can have a temperature of about 52°C and a pressure of about 14 bar.

**[0029]** According to the invention, the method 100 or 200 further includes exchanging heat between a second process water stream and the pressurized partially vaporized refrigerant 104 or 205. The heat exchange between the second process water stream and refrigerant occurs within a second heat exchanger. The second process water stream can be a process water stream exiting from a process plant, as depicted in FIGS. 3 and 4. The second process water stream can have a temperature of about 30°C to about 33°C, *e.g.*, about 31°C, prior to exchanging heat with the refrigerant. After exchanging heat with the refrigerant, the second process water stream can have a temperature of about 38°C to about 42°C, *e.g.*, about 38°C. The refrigerant can have a temperature of about outlet temperature of about 50°C to about 52°C, *e.g.*, about 51°C, and/or have an outlet vapor phase of about 40% to about 55%, *e.g.*, about 40%, after exchanging heat with the second process water stream. The refrigerant can have a vapor fraction of about 60% upon entrance into the second heat exchanger. The method includes combining the second process water stream, after heat exchange with the refrigerant, with the first process water stream, *e.g.*, prior to entrance into the first heat exchanger. The second process water stream becomes the first process water stream, as depicted in FIGS. 3 and 4, to generate a closed process water loop and allow recycling of the second process water stream to the process plant.

**[0030]** According to the invention, the method 100 or 200 further includes lowering the pressure and/or temperature of the pressurized partially vaporized refrigerant 105 or 206. At least a portion of the pressurized partially vaporized refrigerant is transferred from the second heat exchanger to a first expansion valve to lower the pressure and/or temperature of the refrigerant. For example, and not by way of limitation, the pressure of the refrigerant within and/or exiting the first expansion valve can be about 4 bar to about 5 bar, *e.g.*, about 4 bar. Alternatively or additionally, the temperature of the refrigerant within and/or exiting the first expansion valve can be about 10°C to about 13°C, *e.g.*, about 11°C. The vapor fraction of the refrigerant can increase to about 45% to about 75% of the refrigerant, *e.g.*, 45%.

**[0031]** The method 100 or 200 further includes separating the liquid phase from the vapor phase of the refrigerant 106 or 207. At least a portion of the liquid phase of the refrigerant is separated from the vapor phase of the refrigerant to generate a liquid refrigerant. The separation of the vapor phase from the liquid phase of the refrigerant occurs by transferring the refrigerant from the first expansion valve to a vapor-liquid separator. With reference to FIG. 1, the method 100 includes transferring the vapor phase of the refrigerant from the vapor-liquid separator to the multiphase pump. Alternatively, and in reference to FIG. 2, the method 200 can include transferring the vapor phase of the refrigerant from the vapor-liquid separator to the gas compressor.

**[0032]** The method 100 or 200 includes lowering the temperature of the liquid phase of the refrigerant 107 or 208, *e.g.*, to form a cooled liquid refrigerant. Such temperature lowering includes transferring at least a portion of the liquid phase of the refrigerant from the vapor-liquid separator to a second expansion valve. The liquid phase of the refrigerant within or exiting the second expansion valve can include about 1% to about 2%, *e.g.*, 1.5%, of vapor. The temperature of the liquid refrigerant can be lowered to a temperature of about 8°C to about 10°C, e.g., about 9°C. In certain embodiments, the method 100 or 200 further includes transferring the cooled refrigerant to the first heat exchanger for the cooling of the first process stream water, *e.g.*, to generate a closed-loop method for cooling process plant water.

**[0033]** The disclosed subject matter further provides systems for the cooling of process plant water. For example, FIGS. 3 and 4 are schematic representations of systems according to non-limiting embodiments of the disclosed subject matter. In certain embodiments, the system 300 or 400 can include a first heat exchanger 301 or 401. Heat exchangers are used to transfer heat from one medium or phase to another. For example, and not by way of limitation, the first heat exchanger 301 or 401 of the disclosed subject matter are used for exchanging heat between a first process water stream and the liquid refrigerant.

**[0034]** The heat exchangers can be of various designs known in the art. In certain embodiments, the heat exchangers can be double pipe exchangers, and can include a bundle of tubes housed in a shell, such that fluids to be warmed or cooled within the heat exchanger flow through the shell and/or bundle of tubes. In certain embodiments, the heat exchangers can include corrosion-resistant materials, an alloy, *e.g.*, steel or carbon steel, or brazed aluminum.

**[0035]** The first heat exchanger 301 or 401 are coupled to one or more process plant systems 302 or 402. Non-limiting examples of process plant systems are disclosed above. "Coupled" as used herein refers to the connection of a system component to another system component by any means known in the art. The type of coupling used to connect two or more system components can depend on the scale and operability of the system. For example, coupling of two or more components of a system can include one or more joints, valves, transfer lines or sealing elements. Non-limiting examples of joints include threaded joints, soldered joints, welded joints, compression joints and mechanical joints. Non-limiting examples of valves include gate valves, globe valves, ball valves, butterfly valves and check valves.

**[0036]** According to the invention, the system 300 further includes a multiphase pump 303. The multiphase pump for use in the present invention is used used to pump a medium that includes multiple phases, *e.g.*, gas and liquid, to a higher pressure. The multiphase pump 303 is used to increase the pressure of the refrigerant and is coupled to the first heat exchanger 301. Alternatively and/or additionally, and in reference to FIG. 4, the first heat exchanger 401 can be coupled a vapor-liquid separator 403, *e.g.*, a flash drum, for the separation of the liquid and gas phases of the refrigerant. The vapor-liquid separator 403 can be further coupled to a liquid pump 409, for pumping the separated liquid phase of the refrigerant.

**[0037]** The system 300 or 400 includes a second heat exchanger 304 or 404 for exchanging heat between a second process water stream, *e.g.*, transferred from the process plant system 302 or 402, and the partially vaporized refrigerant. Examples of heat exchangers are disclosed above. The second heat exchanger 304 is coupled to the multiphase pump 303. Alternatively, and in reference to FIG. 4, the second heat exchanger 404 can be coupled to the liquid pump 409 for the transfer of the liquid phase of the refrigerant from the vapor-liquid separator 403 to the second heat exchanger 404. The liquid pump 409 can be coupled to the second heat exchanger 404 via a transfer line 411. The vapor-liquid separator 403 of system 400 can be coupled to a gas compressor 410 for compressing the separated vapor phase of the refrigerant. The gas compressor 410 can, in turn, be coupled to the second heat exchanger 404 for combining the compressed vapor phase of the refrigerant with the separated liquid phase to generate a partially vaporized refrigerant and to transfer the partially vaporized refrigerant to the second heat exchanger 404. The gas compressor 410 can be coupled to the second heat exchanger 404 via the transfer line 411.

**[0038]** The second heat exchanger 304 or 404 is further coupled to the first heat exchanger 301 or 401. The second heat exchanger 304 or 404 is coupled to the first heat exchanger 301 or 401 through a liquid pump 308 or 408, *e.g.*, for the transfer of the second process water stream from the second heat exchanger 304 or 404 to the first heat exchanger 301 or 401. Non-limiting examples of liquid pumps for use in the present invention include peristaltic pumps, pneumatic pumps, diaphragm pumps, piston pumps, rotary pumps, centrifugal pumps, positive displacement pumps and reciprocating pumps.

**[0039]** The system 300 or 400 further includes a first expansion valve 305 or 405 for lowering the temperature of the partially vaporized refrigerant. Expansion valves can change the temperature of a medium, *e.g.*, a refrigerant, by altering the pressure. The pressure within the first expansion valve 305 or 405 can be in a range from about 4 bar to about 5 bar. The first expansion valve 305 or 405 can be coupled to the second heat exchanger 304 or 404.

**[0040]** The system 300 or 400 further includes a vapor-liquid separator, *e.g.*, a flash drum, 306 or 406 for separating the liquid and vapor phases of the refrigerant. The vapor-liquid separator 306 or 406 are coupled to the first expansion valve 305 or 405. In certain embodiments, and in reference to FIG. 3, the vapor-liquid separator 306 can be coupled to the multiphase pump 303 for transferring at least a portion of the separated vapor phase of the refrigerant to the multiphase pump 303. Alternatively or additionally, and in reference to FIG. 4, the vapor-liquid separator 406 can be coupled to the gas compressor 410, *e.g.*, for the transfer of at least a portion of the separated vapor phase to the gas compressor 410.

**[0041]** The system 300 or 400 includes a second expansion valve 307 or 407 for lowering the temperature of the liquid phase of the refrigerant. The second expansion valve 307 or 407 can be coupled to the vapor-liquid separator 306 or 406. The second expansion valve 307 or 407 coupled to the first heat exchanger 301 or 401 for the transfer of the refrigerant to the first heat exchanger 301 or 401, to exchange heat with the first process water stream.

**[0042]** The following example is illustrative of the presently disclosed subject matter and should not be considered as a limitation in any way.

**EXAMPLE 1:**

**[0043]** A simulation using the software PRO/II (Invensys Systems, Inc.) was performed to demonstrate a method for cooling process plant water according to one non-limiting embodiment of the disclosed subject matter (FIG. 3). In method simulation software such as, for example, PRO/II, each process component (*e.g.*, flash drum, heat exchanger, etc.) of a user-specified process design/system is mathematically modeled including by each piece of equipment, effluent streams, and attributes of chemical components. Interconnections and the interaction between components are also integral to the model. Table 1 shows the changes in the temperature, pressure and vapor fraction of the process plant water and refrigerant during the simulation.

**[0044]** The simulated method included the use of a liquid refrigerant having a temperature of 9°C to cool down a process water stream from a temperature of 38°C to a chilled water temperature of 25°C in a first heat exchanger (HX1). In this Example, the refrigerant R134A was used in the simulation. The refrigerant exiting the heat exchanger had a temperature of 6.7°C with a vapor phase fraction of 40%. The refrigerant was then combined with a vapor stream coming from a flash drum further downstream and the refrigerant was fed to a multiphase pump where the pressure of the refrigerant was raised from 3.7 bar to 13.9 bar. The heat generated from the pump increased the refrigerant temperature from an inlet temperature of 7.4°C to an outlet temperature of 52.1°C with a vapor fraction of 54.4% (Table 1).

**[0045]** The cooled process water was transferred to a plant process where it cooled down different streams in the plant with a total duty of 25.8 MW and exited the plant with an outlet water temperature of 31.1°C. The refrigerant was then fed to a second heat exchanger (HX2) where it is cooled down against the process water exiting the plant. The temperature of the process water increased from 31.1°C to 38°C and the refrigerant cooled to 51.5°C with vapor fraction of 41%. The process water was then pumped back to the first heat exchanger (HX1). The refrigerant was then cooled by lowering its pressure in an expansion valve (EV1) to 4.3 bar, where its temperature decreased to 11.2°C. The vapor was then separated from the liquid by a flash drum and was combined with the multiphase pump inlet feed mixture. The liquid stream was fed to a second expansion valve (EV2) where its pressure was lowered to 4 bar forming a mixture with 1.5% gas fraction with a temperature of 9°C. The mixture was recycled back to the first heat exchanger. The liquid in the mixture to the multiphase pump had a viscosity of 0.25 centipoise (cP), which is within the operating specification of the multiphase pumps.

**Table 1**

| Stream | Flow rate (t/h) | Pressure (bar) | Temperature (°C) | Vapor fraction (%) |
|---|---|---|---|---|
| Inlet process water to HX1 | 3434.66 | 5.00 | 38.00 | 0.0 |
| Outlet process water from HX1 | 3434.66 | 4.50 | 25.03 | 0.0 |
| Inlet refrigerant to HX1 | 2713.41 | 4.00 | 9.04 | 1.5 |
| Outlet refrigerant from HX1 | 2713.41 | 3.70 | 6.74 | 40.0 |
| Inlet refrigerant to multiphase pump | 4899.97 | 3.70 | 6.74 | 66.8 |
| Outlet refrigerant from multiphase pump | 4899.97 | 13.90 | 52.14 | 54.4 |
| Outlet refrigerant from HX2 | 4899.97 | 13.70 | 51.56 | 41.1 |
| Inlet process water to HX2 | 3434.66 | 4.47 | 31.12 | 0.0 |
| Outlet refrigerant from EV1 | 4899.97 | 4.30 | 11.21 | 44.8 |

**[0046]** The foregoing description of specific embodiments of the disclosed subject matter has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosed subject matter to those embodiments disclosed. It will be apparent to those skilled in the art that various modifications and variations can be made in the compositions and methods within the scope of the invention as defined in the appended claims.

## Claims

1. A method (100; 200) for cooling process plant water, the method comprising:

(a) exchanging (101; 201) heat between a first process water stream and a liquid refrigerant within a first heat exchanger (301; 401) to lower the temperature of the process water stream, thereby partially vaporizing the refrigerant upon the exchange of heat with the first process water stream;
(b) transferring (102; 202) the first process water from the first heat exchanger (301; 401) to one or more process plants (302; 402);
(c) transferring the partially vaporized refrigerant from the first heat exchanger (301; 401) to a multiphase pump (303) to increase the pressure of the partially vaporized refrigerant, wherein a multiphase pump (303) is for pumping a medium that includes multiple phases to a higher pressure;
(d) transferring the partially vaporized refrigerant from the multiphase pump (303) to a second heat exchanger (304; 404);
(e) exchanging heat between a second process water stream and the partially vaporized refrigerant within the second heat exchanger (304; 404) to decrease the temperature of the refrigerant;
(f) transferring the second process water stream from the second heat exchanger (304; 404) to become the first process water stream entering the first heat exchanger (301; 401);
(g) transferring the partially vaporized refrigerant from the second heat exchanger (304; 404) to a first expansion valve (305; 405) to lower the pressure and/or temperature of the refrigerant;
(h) transferring the partially vaporized refrigerant from the first expansion valve (305; 405) to a vapor-liquid separator (306; 406) to separate the liquid phase from the vapor phase thereof, thereby generating a liquid refrigerant;
(i) transferring the liquid refrigerant from the vapor-liquid separator (306; 406) to a second expansion valve (307; 407) to lower the temperature of the liquid refrigerant; and
(j) transferring the refrigerant from the second expansion valve (307; 407) to the first heat exchanger (301; 401) to exchange heat with the first process water stream.

**2.** The method of claim 1, wherein the liquid refrigerant comprises a refrigerant having a viscosity greater than or equal to about 0.1 cP at a temperature of about 0°C.

**3.** The method of claim 2, wherein the liquid refrigerant comprises a refrigerant having a viscosity from about 0.1 cP to about 1.0 cP.

**4.** The method of claim 1, wherein the liquid refrigerant comprises a refrigerant having a boiling point temperature from about -10°C to about -50°C.

**5.** The method of claim 1, wherein the liquid refrigerant comprises a refrigerant having a boiling point temperature from about -20°C to about -50°C.

**6.** The method of claim 1, wherein the liquid refrigerant comprises a refrigerant selected from the group consisting of R134A, R404A, R407C, R125, and R410A.

**7.** The method of claim 1, wherein the partially vaporized refrigerant comprises a refrigerant having a vapor phase of about 30% to about 50%.

**8.** The method of claim 1, wherein the vapor-liquid separator comprises a flash drum.

**9.** The method of claim 1, further including transferring the vapor phase of the refrigerant to a gas compressor (410) for the compression of the refrigerant.

**10.** The method of claim 9, including combining the compressed vapor phase of the refrigerant with the liquid phase of the refrigerant to generate a pressurized partially vaporized refrigerant.

**11.** A system comprising
a heat exchanging system for exchanging heat between a first process water stream and a second process water stream with a refrigerant, and
one or more of a process plant system,
wherein the system comprises:

(a) a first heat exchanger (301; 401) for exchanging heat between the first process water stream and the refrigerant and thereby generate a partially vaporized refrigerant having liquid and vapor phases, wherein the

first heat exchanger (301; 401) is coupled to the one or more of a process plant system (302; 402);
(b) a multiphase pump (303), coupled to the first heat exchanger, to increase the partially vaporized refrigerant pressure, wherein a multiphase pump is for pumping a medium that includes multiple phases to a higher pressure;
(c) a second heat exchanger (304; 404), coupled to the multiphase pump (303) and the first heat exchanger (301; 401), for exchanging heat between the second process water stream transferred from the one or more of a process plant system (302; 402) and the partially vaporized refrigerant, wherein the second heat exchanger (304; 404) is coupled to the first heat exchanger (301; 401) through a liquid pump (308; 408) for the transfer of the second process water stream from the second heat exchanger (304; 404) to the first heat exchanger (301; 401);
(d) a first expansion valve (305; 405), coupled to the second heat exchanger (304; 404), for lowering the pressure and/or temperature of the partially vaporized refrigerant;
(e) a vapor-liquid separator (306; 406), coupled to the first expansion valve (305; 405) and the multiphase pump (303), for separating the liquid and the vapor phases of the partially vaporized refrigerant; and
(f) a second expansion valve (307; 407), coupled to the vapor-liquid separator (306; 406) and the first heat exchanger (301; 401), for lowering the liquid phase temperature of the refrigerant.

**12.** The system of claim 11, wherein the vapor-liquid separator comprises a flash drum.

**13.** The system of claim 11, including a further vapor-liquid separator (403), coupled to the first heat exchanger (401), to separate the vapor phase from the liquid phase of the refrigerant, and a gas compressor (410), coupled to the further vapor-liquid separator (403), wherein the gas compressor (410) is for increasing the pressure of the vapor phase of the refrigerant.

**14.** The system of claim 13, wherein the gas compressor (410) is coupled to the second heat exchanger (404) for combining a compressed vapor phase of the refrigerant with a separated liquid phase to generate a partially vaporized refrigerant and to transfer the partially vaporized refrigerant to the second heat exchanger (404).

**15.** The system of claim 13 or 14, further including a pump (409), coupled to the further vapor-liquid separator (403), for transferring at least a portion of the liquid phase of the refrigerant, and including a transfer line (411), coupled to the gas compressor (410) and the pump (409), for combining the vapor phase of the refrigerant and a compressed liquid phase of the refrigerant, thereby generating a partially vaporized refrigerant, wherein the second heat exchanger (404) is coupled to the transfer line (411).

## Patentansprüche

**1.** Verfahren (100, 200) zum Kühlen von Prozessanlagenwasser, wobei das Verfahren umfasst:

(a) Austauschen (101; 201) von Wärme zwischen einem ersten Prozesswasserstrom und einem flüssigen Kühlmittel in einem ersten Wärmetauscher (301; 401), um die Temperatur des Prozesswasserstroms zu senken, wodurch das Kühlmittel beim Austauschen von Wärme mit dem ersten Prozesswasserstrom teilweise verdampft wird;
(b) Überführen (102;202) des ersten Prozesswassers vom ersten Wärmetauscher (301; 401) zu einer oder mehreren Prozessanlagen (302; 402);
(c) Überführen des teilweise verdampften Kühlmittels vom ersten Wärmetauscher (301; 401) zu einer Mehrphasenpumpe (303), um den Druck des teilweise verdampften Kühlmittels zu erhöhen, wobei eine Mehrphasenpumpe (303) dazu dient, ein Medium, das mehrere Phasen aufweist, auf einen höheren Druck zu pumpen;
(d) Überführen des teilweise verdampften Kühlmittels von der Mehrphasenpumpe (303) zu einem zweiten Wärmetauscher (304; 404) ;
(e) Austauschen von Wärme zwischen einem zweiten Prozesswasserstrom und dem teilweise verdampften Kühlmittel in dem zweiten Wärmetauscher (304; 404), um die Temperatur des Kühlmittels zu senken;
(f) Überführen des zweiten Prozesswasserstroms vom zweiten Wärmetauscher (304; 404), so dass dieser der erste Prozesswasserstrom wird, der in den ersten Wärmetauscher (301; 401) eintritt;
(g) Überführen des teilweise verdampften Kühlmittels vom zweiten Wärmetauscher (304; 404) zu einem ersten Expansionsventil (305; 405), um den Druck und/oder die Temperatur des Kühlmittels zu senken;
(h) Überführen des teilweise verdampften Kühlmittels vom ersten Expansionsventil (305; 405) zu einem Dampf-Flüssigkeit-Abscheider (306; 406), um seine Flüssigkeitsphase von seiner Dampfphase zu trennen, wodurch ein flüssiges Kühlmittel erzeugt wird;

(i) Überführen des flüssigen Kühlmittels vom Dampf-Flüssigkeit-Abscheider (306; 406) zu einem zweiten Expansionsventil (307; 407), um die Temperatur des flüssigen Kühlmittels zu senken; und
(j) Überführen des Kühlmittels vom zweiten Expansionsventil (307; 407) zum ersten Wärmetauscher (301; 401), um mit dem ersten Prozesswasserstrom Wärme auszutauschen.

**2.** Verfahren nach Anspruch 1, wobei das flüssige Kühlmittel ein Kühlmittel mit einer Viskosität von über oder gleich etwa 0,1 cP bei einer Temperatur von etwa 0 °C umfasst.

**3.** Verfahren nach Anspruch 2, wobei das flüssige Kühlmittel ein Kühlmittel mit einer Viskosität von etwa 0,1 cP bis etwa 1,0 cP umfasst.

**4.** Verfahren nach Anspruch 1, wobei das flüssige Kühlmittel ein Kühlmittel mit einer Siedepunkttemperatur von etwa -10 °C bis etwa -50°C umfasst.

**5.** Verfahren nach Anspruch 1, wobei das flüssige Kühlmittel ein Kühlmittel mit einer Siedepunkttemperatur von etwa -20°C bis etwa -50°C umfasst.

**6.** Verfahren nach Anspruch 1, wobei das flüssige Kühlmittel ein Kühlmittel umfasst, das ausgewählt ist aus der Gruppe bestehend aus R134A, R404A, R407C, R125 und R410A.

**7.** Verfahren nach Anspruch 1, wobei das teilweise verdampfte Kühlmittel ein Kühlmittel mit einer Dampfphase von etwa 30 % bis etwa 50 % umfasst.

**8.** Verfahren nach Anspruch 1, wobei der Dampf-Flüssigkeit-Abscheider eine Entspannungsverdampfungstrommel umfasst.

**9.** Verfahren nach Anspruch 1, ferner das Überführen der Dampfphase des Kühlmittels zu einem Gasverdichter (410) für die Verdichtung des Kühlmittels einschließend.

**10.** Verfahren nach Anspruch 9, das Kombinieren der verdichteten Dampfphase des Kühlmittels mit der Flüssigkeitsphase des Kühlmittels umfassend, um ein unter Druck stehendes teilweise verdampftes Kühlmittel zu erzeugen.

**11.** System, umfassend:

ein Wärmetauschersystem zum Austauschen von Wärme zwischen einem ersten Prozesswasserstrom und einem zweiten Prozesswasserstrom und einem Kühlmittel und
mindestens ein Prozessanlagensystem, wobei das System umfasst:

(a) einen ersten Wärmetauscher (301; 401), um Wärme zwischen dem ersten Prozesswasserstrom und dem Kühlmittel auszutauschen und um dadurch ein teilweise verdampftes Kühlmittel mit einer Flüssigkeits- und einer Dampfphase zu erzeugen, wobei der erste Wärmetauscher (301; 401) mit dem mindestens einen Prozessanlagensystem (302; 402) gekoppelt ist;
(b) eine Mehrphasenpumpe (303), die mit dem ersten Wärmetauscher gekoppelt ist, um den Druck des teilweise verdampften Kühlmittels zu erhöhen, wobei eine Mehrphasenpumpe dazu dient, ein Medium, das mehrere Phasen aufweist, auf einen höheren Druck zu pumpen;
(c) einen zweiten Wärmetauscher (304; 404), der mit der Mehrphasenpumpe (303) und dem ersten Wärmetauscher (301; 401) gekoppelt ist, um Wärme zwischen dem zweiten Prozesswasserstrom, der von dem mindestens einen Prozessanlagensystem (302; 402) überführt wird, und dem teilweise verdampften Kühlmittel auszutauschen, wobei der zweite Wärmetauscher (304; 404) über eine Flüssigkeitspumpe (308; 408) mit dem ersten Wärmetauscher (301; 401) gekoppelt ist, um den zweiten Prozesswasserstrom vom zweiten Wärmetauscher (304; 404) zum ersten Wärmetauscher (301; 401) zu überführen;
(d) ein erstes Expansionsventil (305; 405), das mit dem zweiten Wärmetauscher (304; 404) gekoppelt ist, um den Druck und/oder die Temperatur des teilweise verdampften Kühlmittels zu senken;
(e) einen Dampf-Flüssigkeit-Abscheider (306; 406), der mit dem ersten Expansionsventil (305; 405) und der Mehrphasenpumpe (303) gekoppelt ist, um die Flüssigkeits- und die Dampfphase des teilweise verdampften Kühlmittels voneinander zu trennen; und
(f) ein zweites Expansionsventil (307; 407), das mit dem Dampf-Flüssigkeit-Abscheider (306; 406) und dem ersten Wärmetauscher (301; 401) gekoppelt ist, um die Temperatur der Flüssigkeitsphase des Kühlmittels

zu senken.

12. System nach Anspruch 11, wobei der Dampf-Flüssigkeit-Abscheider eine Entspannungsverdampfungstrommel umfasst.

13. System nach Anspruch 11 mit einem weiteren Dampf-Flüssigkeit-Abscheider (403), der mit dem ersten Wärmetauscher (401) gekoppelt ist, um die Dampfphase von der Flüssigkeitsphase des Kühlmittels zu trennen, und einem Gasverdichter (410), der mit dem weiteren Dampf-Flüssigkeit-Abscheider (403) gekoppelt ist, wobei der Gasverdichter (410) dazu dient, den Druck der Dampfphase des Kühlmittels zu erhöhen.

14. System nach Anspruch 13, wobei der Gasverdichter (410) mit dem zweiten Wärmetauscher (404) gekoppelt ist, um eine verdichtete Dampfphase des Kühlmittels mit einer abgetrennten Flüssigkeitsphase zu kombinieren, um ein teilweise verdampftes Kühlmittel zu erzeugen und um das teilweise verdampfte Kühlmittel zum zweiten Wärmetauscher (404) zu überführen.

15. System nach Anspruch 13 oder 14, ferner eine Pumpe (409) umfassend, die mit dem weiteren Dampf-Flüssigkeit-Abscheider (403) gekoppelt ist, um zumindest einen Teil der Flüssigkeitsphase des Kühlmittels zu überführen, und eine Überführungsleitung (411) aufweisend, die mit dem Gasverdichter (410) und der Pumpe (409) gekoppelt ist, um die Dampfphase des Kühlmittels und eine verdichtete Flüssigkeitsphase des Kühlmittels zu kombinieren, wodurch ein teilweise verdampftes Kühlmittel erzeugt wird, wobei der zweite Wärmetauscher (404) mit der Überführungsleitung (411) gekoppelt ist.

## Revendications

1. Procédé (100 ; 200) de refroidissement d'eau d'installation de traitement, le procédé comprenant :

   (a) l'échange (101 ; 201) de chaleur entre un premier courant d'eau de traitement et un frigorigène liquide au sein d'un premier échangeur de chaleur (301 ; 401) pour abaisser la température du courant d'eau de traitement, vaporisant ainsi partiellement le frigorigène lors de l'échange de chaleur avec le premier courant d'eau de traitement ;
   (b) le transfert (102 ; 202) de la première eau de traitement du premier échangeur de chaleur (301 ; 401) à une ou plusieurs installations de traitement (302 ; 402) ;
   (c) le transfert du frigorigène partiellement vaporisé du premier échangeur de chaleur (301 ; 401) à une pompe multiphase (303) pour augmenter la pression du frigorigène partiellement vaporisé, dans lequel une pompe multiphase (303) est destinée à pomper un milieu qui inclut de multiples phases à une plus haute pression ;
   (d) le transfert du frigorigène partiellement vaporisé de la pompe multiphase (303) à un second échangeur de chaleur (304 ; 404) ;
   (e) l'échange de chaleur entre un second courant d'eau de traitement et le frigorigène partiellement vaporisé au sein du second échangeur de chaleur (304 ; 404) pour diminuer la température du frigorigène ;
   (f) le transfert du second courant d'eau de traitement du second échangeur de chaleur (304 ; 404) pour qu'il devienne le premier courant d'eau de traitement entrant dans le premier échangeur de chaleur (301 ; 401) ;
   (g) le transfert du frigorigène partiellement vaporisé du second échangeur de chaleur (304 ; 404) à une première vanne de détente (305 ; 405) pour abaisser la pression et/ou la température du frigorigène ;
   (h) le transfert du frigorigène partiellement vaporisé de la première vanne de détente (305 ; 405) à un séparateur vapeur-liquide (306 ; 406) pour séparer la phase liquide de sa phase vapeur, générant ainsi un frigorigène liquide ;
   (i) le transfert du frigorigène liquide du séparateur vapeur-liquide (306 ; 406) à une seconde vanne de détente (307 ; 407) pour abaisser la température du frigorigène liquide ; et
   (j) le transfert du frigorigène de la seconde vanne de détente (307 ; 407) au premier échangeur de chaleur (301 ; 401) pour échanger de la chaleur avec le premier courant d'eau de traitement.

2. Procédé selon la revendication 1, dans lequel le frigorigène liquide comprend un frigorigène ayant une viscosité supérieure ou égale à environ 0,1 cP à une température d'environ 0 °C.

3. Procédé selon la revendication 2, dans lequel le frigorigène liquide comprend un frigorigène ayant une viscosité d'environ 0,1 cP à environ 1,0 cP.

**4.** Procédé selon la revendication 1, dans lequel le frigorigène liquide comprend un frigorigène ayant une température de point d'ébullition d'environ -10 °C à environ -50 °C.

**5.** Procédé selon la revendication 1, dans lequel le frigorigène liquide comprend un frigorigène ayant une température de point d'ébullition d'environ -20 °C à environ -50 °C.

**6.** Procédé selon la revendication 1, dans lequel le frigorigène liquide comprend un frigorigène choisi dans le groupe consistant en R134A, R404A, R407C, R125, et R410A.

**7.** Procédé selon la revendication 1, dans lequel le frigorigène partiellement vaporisé comprend un frigorigène ayant une phase vapeur d'environ 30 % à environ 50 %.

**8.** Procédé selon la revendication 1, dans lequel le séparateur vapeur-liquide comprend un séparateur instantané.

**9.** Procédé selon la revendication 1, incluant en outre le transfert de la phase vapeur du frigorigène à un compresseur de gaz (410) pour la compression du frigorigène.

**10.** Procédé selon la revendication 9, incluant la combinaison de la phase vapeur comprimée du frigorigène avec la phase liquide du frigorigène pour générer un frigorigène partiellement vaporisé pressurisé.

**11.** Système comprenant
un système d'échange de chaleur destiné à échanger de la chaleur entre un premier courant d'eau de traitement et un second courant d'eau de traitement avec un frigorigène, et
un ou plusieurs d'un système d'installation de traitement, dans lequel le système comprend :

(a) un premier échangeur de chaleur (301 ; 401) destiné à échanger de la chaleur entre le premier courant d'eau de traitement et le frigorigène et générer ainsi un frigorigène partiellement vaporisé ayant des phases liquide et vapeur, dans lequel le premier échangeur de chaleur (301 ; 401) est couplé aux un ou plusieurs d'un système d'installation de traitement (302 ; 402) ;
(b) une pompe multiphase (303), couplée au premier échangeur de chaleur, pour augmenter la pression du frigorigène partiellement vaporisé, dans lequel une pompe multiphase est destinée à pomper un milieu qui inclut de multiples phases à une plus haute pression ;
(c) un second échangeur de chaleur (304 ; 404), couplé à la pompe multiphase (303) et au premier échangeur de chaleur (301 ; 401), destiné à échanger de la chaleur entre le second courant d'eau de traitement transféré des un ou plusieurs d'un système d'installation de traitement (302 ; 402) et le frigorigène partiellement vaporisé, dans lequel le second échangeur de chaleur (304 ; 404) est couplé au premier échangeur de chaleur (301 ; 401) par le biais d'une pompe à liquide (308 ; 408) pour le transfert du second courant d'eau de traitement du second échangeur de chaleur (304 ; 404) au premier échangeur de chaleur (301 ; 401) ;
(d) une première vanne de détente (305 ; 405), couplée au second échangeur de chaleur (304 ; 404), destinée à abaisser la pression et/ou la température du frigorigène partiellement vaporisé ;
(e) un séparateur vapeur-liquide (306 ; 406), couplé à la première vanne de détente (305 ; 405) et à la pompe multiphase (303), destiné à séparer les phases liquide et vapeur du frigorigène partiellement vaporisé ; et
(f) une seconde vanne de détente (307 ; 407), couplée au séparateur vapeur-liquide (306 ; 406) et au premier échangeur de chaleur (301 ; 401), destinée à abaisser la température de la phase liquide du frigorigène.

**12.** Système selon la revendication 11, dans lequel le séparateur vapeur-liquide comprend un séparateur instantané.

**13.** Système selon la revendication 11, incluant un séparateur vapeur-liquide supplémentaire (403), couplé au premier échangeur de chaleur (401), pour séparer la phase vapeur de la phase liquide du frigorigène, et un compresseur de gaz (410), couplé au séparateur vapeur-liquide supplémentaire (403), dans lequel le compresseur de gaz (410) est destiné à augmenter la pression de la phase vapeur du frigorigène.

**14.** Système selon la revendication 13, dans lequel le compresseur de gaz (410) est couplé au second échangeur de chaleur (404) pour combiner une vapeur comprimée du frigorigène avec une phase liquide séparée pour générer un frigorigène partiellement vaporisé et transférer le frigorigène partiellement vaporisé au second échangeur de chaleur (404).

**15.** Système selon la revendication 13 ou 14, incluant en outre une pompe (409), couplée au séparateur vapeur-liquide supplémentaire (403), destinée à transférer au moins une portion de la phase liquide du frigorigène, et incluant une ligne de transfert (411), couplée au compresseur de gaz (410) et à la pompe (409), destinée à combiner la phase vapeur du frigorigène et une phase liquide comprimée du frigorigène, générant ainsi un frigorigène partiellement vaporisé, dans lequel le second échangeur de chaleur (404) est couplé à la ligne de transfert (411).

FIG. 1

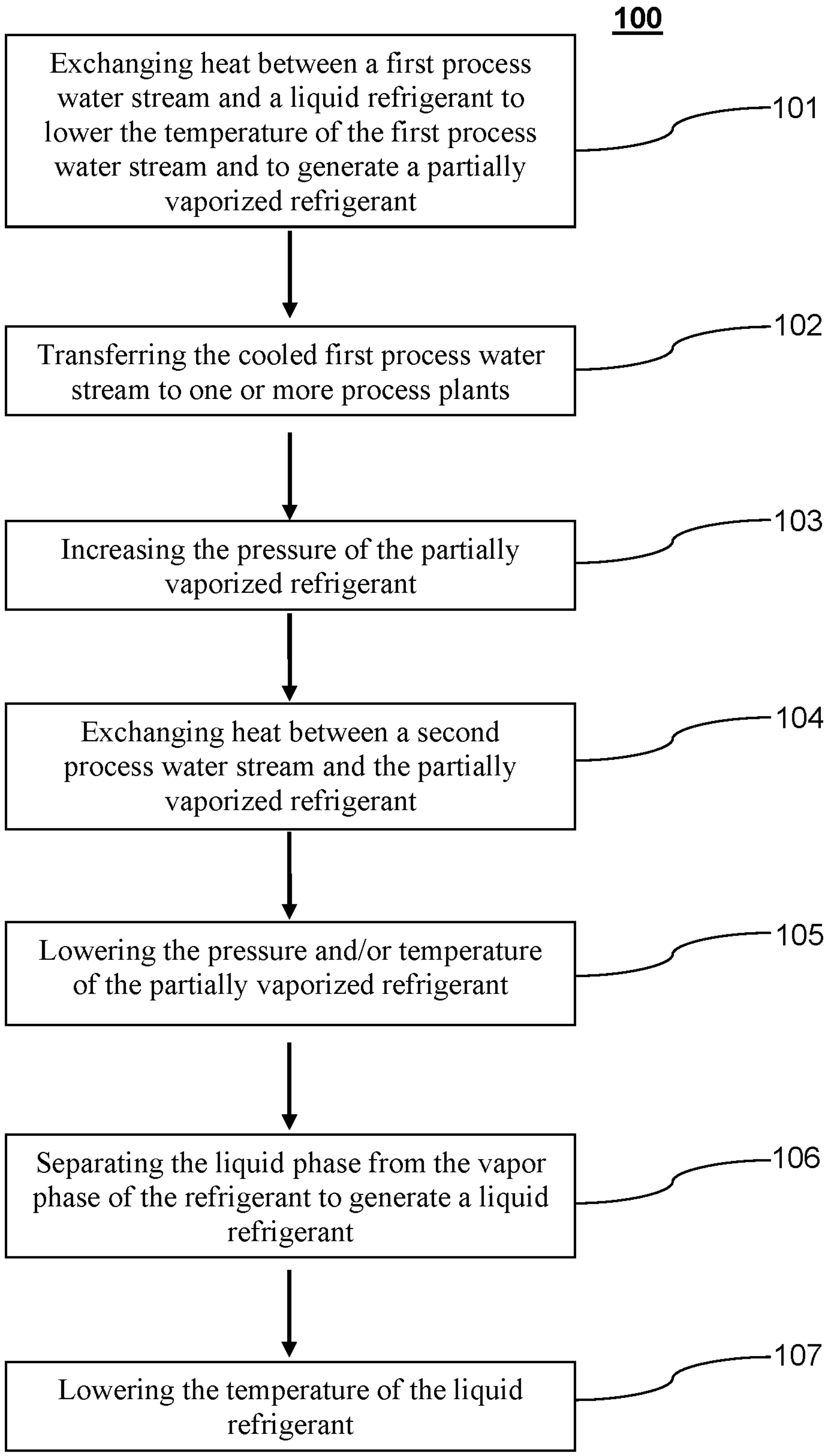

100
Exchanging heat between a first process water stream and a liquid refrigerant to lower the temperature of the first process water stream and to generate a partially vaporized refrigerant
101
Transferring the cooled first process water stream to one or more process plants
102
Increasing the pressure of the partially vaporized refrigerant
103
Exchanging heat between a second process water stream and the partially vaporized refrigerant
104
Lowering the pressure and/or temperature of the partially vaporized refrigerant
105
Separating the liquid phase from the vapor phase of the refrigerant to generate a liquid refrigerant
106
Lowering the temperature of the liquid refrigerant
107

FIG. 2

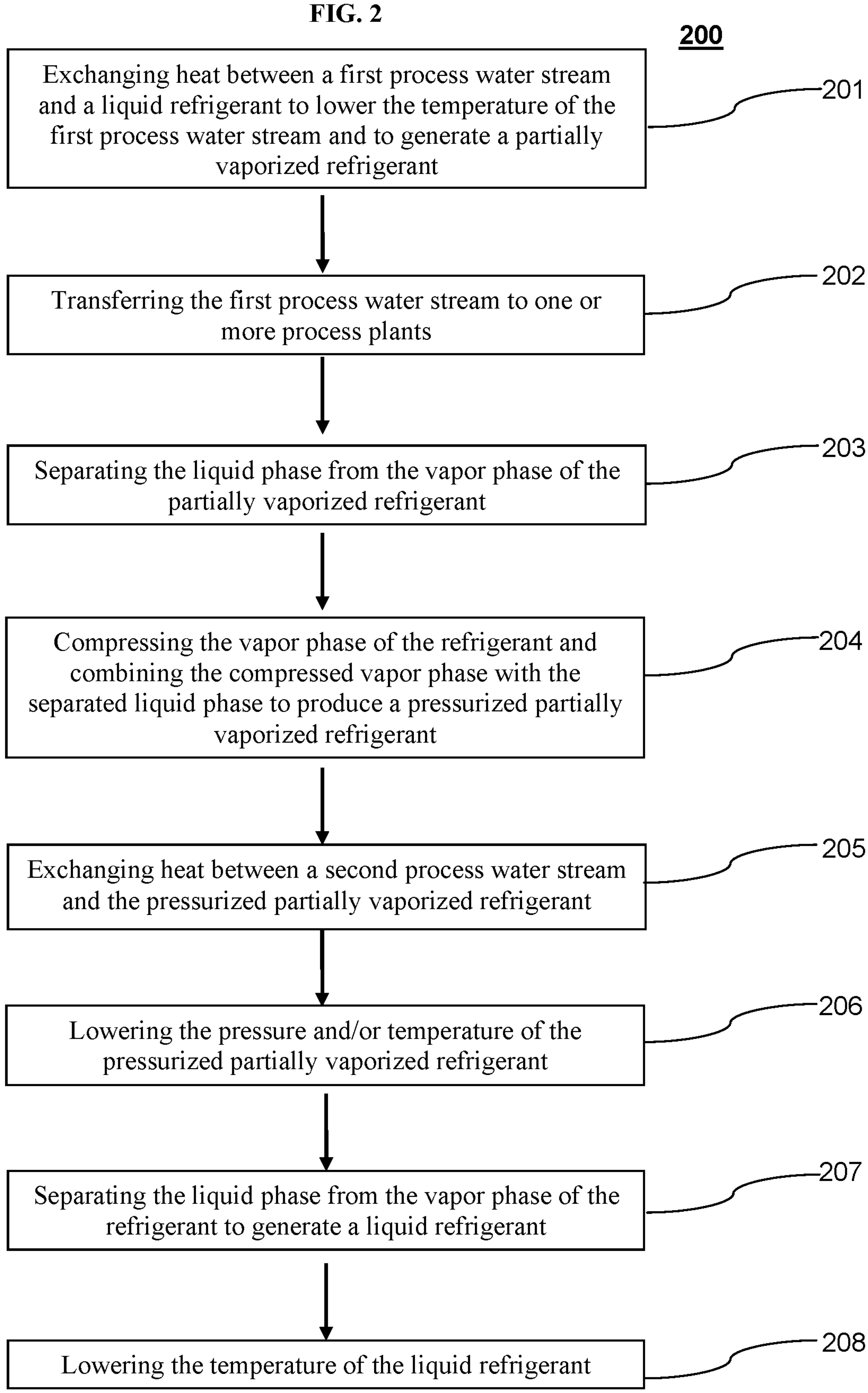

200
Exchanging heat between a first process water stream and a liquid refrigerant to lower the temperature of the first process water stream and to generate a partially vaporized refrigerant
201
Transferring the first process water stream to one or more process plants
202
Separating the liquid phase from the vapor phase of the partially vaporized refrigerant
203
Compressing the vapor phase of the refrigerant and combining the compressed vapor phase with the separated liquid phase to produce a pressurized partially vaporized refrigerant
204
Exchanging heat between a second process water stream and the pressurized partially vaporized refrigerant
205
Lowering the pressure and/or temperature of the pressurized partially vaporized refrigerant
206
Separating the liquid phase from the vapor phase of the refrigerant to generate a liquid refrigerant
207
Lowering the temperature of the liquid refrigerant
208

FIG. 3

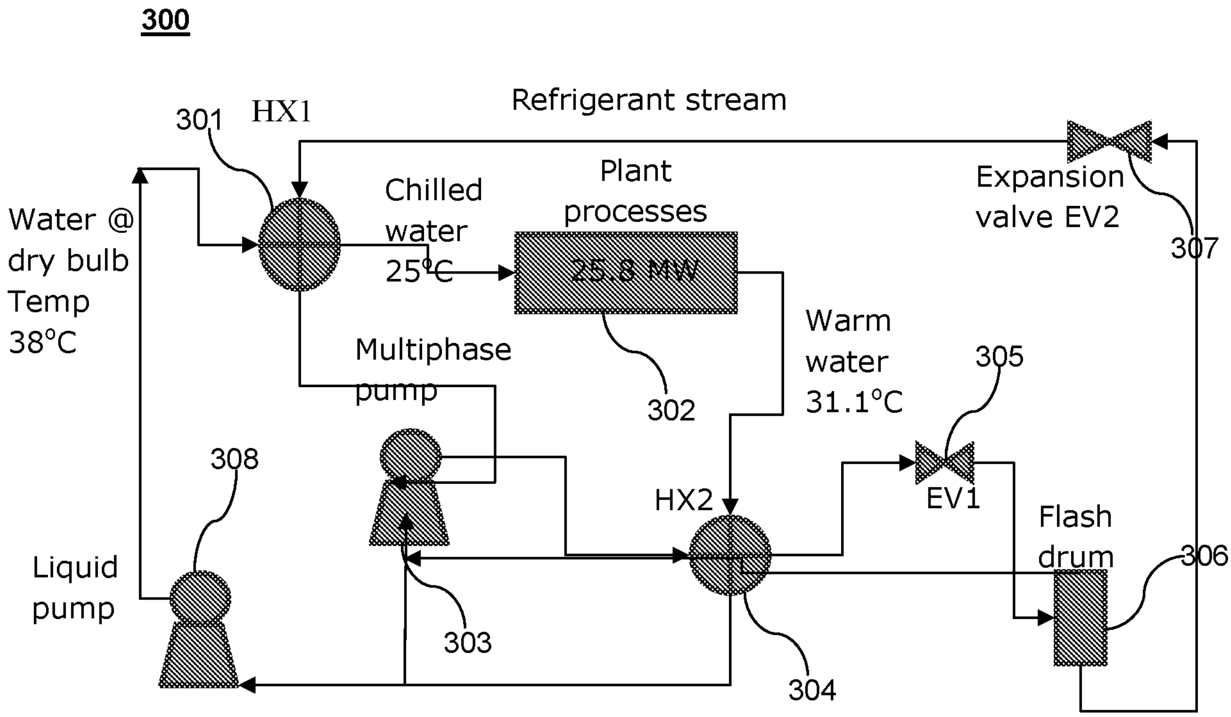
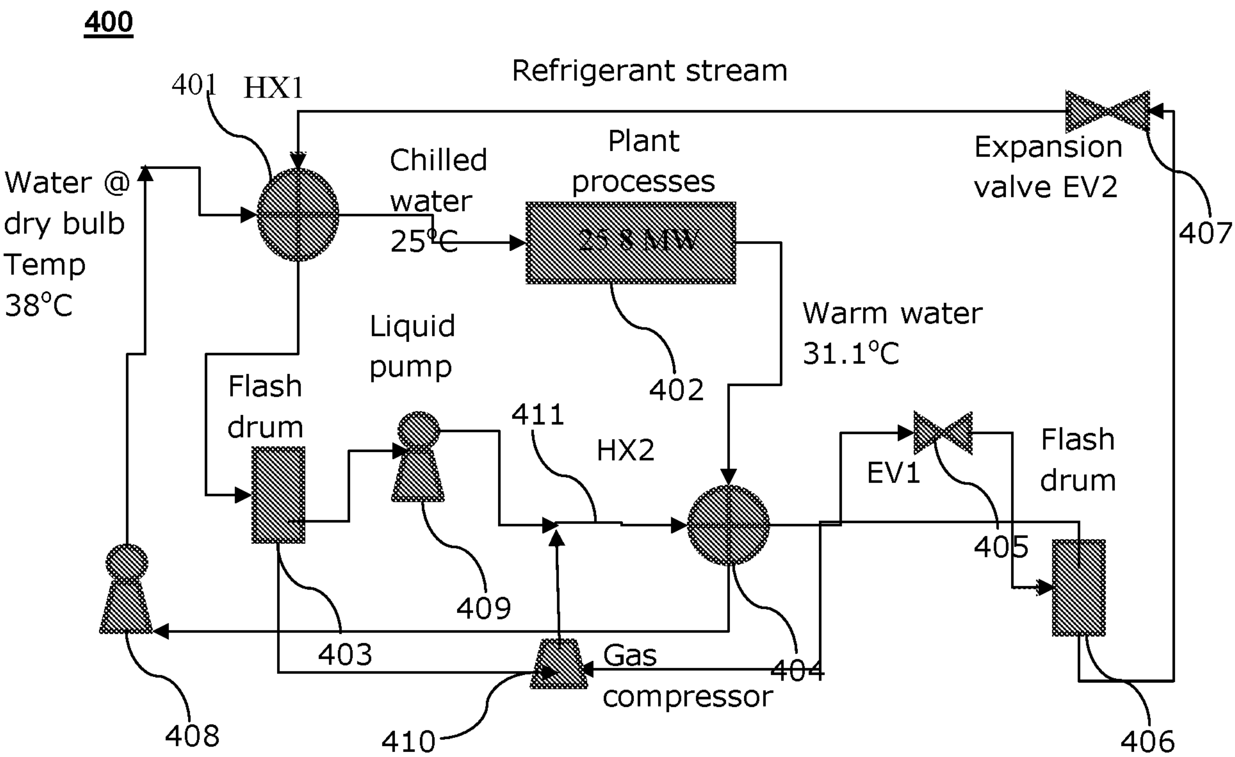

300
Refrigerant stream
301
HX1
Chilled
water
25°C
Plant
processes
25.8 MW
Expansion
valve EV2
307
Water @
dry bulb
Temp
38°C
Warm
water
31.1°C
Multiphase
pump
302
305
308
HX2
EV1
Flash
drum
306
Liquid
pump
303
304

**FIG. 4**


400
Refrigerant stream
401
HX1
Water @ dry bulb Temp 38°C
Chilled water 25°C
Plant processes
25.8 MW
Expansion valve EV2
407
Liquid pump
402
Warm water 31.1°C
Flash drum
411
HX2
EV1
Flash drum
405
403
409
404
Gas compressor
408
410
406

## REFERENCES CITED IN THE DESCRIPTION

*This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.*

### Patent documents cited in the description


- EP 2426433 A2 **[0003]**