(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 542 112 A1

(12) # EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
23.04.2025 Bulletin 2025/17

(21) Application number: **24793099.3**

(22) Date of filing: **19.02.2024**

(51) International Patent Classification (IPC):
F22B 1/18 (2006.01) ***F22B 31/04*** (2006.01)
F24D 17/00 (2022.01) ***F25B 27/02*** (2006.01)

(52) Cooperative Patent Classification (CPC):
F22B 1/18; F22B 31/04; F24D 17/00; F25B 27/02

(86) International application number:
PCT/KR2024/095367

(87) International publication number:
WO 2024/219915 (24.10.2024 Gazette 2024/43)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
GE KH MA MD TN

(30) Priority: **18.04.2023 KR 20230050549**
15.02.2024 KR 20240021815

(71) Applicant: **LG Chem, Ltd.**
Seoul 07336 (KR)

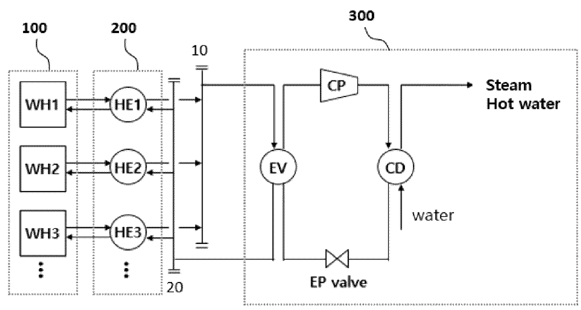
(72) Inventors:
- **OH, Suk Yung**
Daejeon 34122 (KR)
- **HWANG, Jeong A**
Daejeon 34122 (KR)
- **LEE, Sang Yoon**
Daejeon 34122 (KR)
- **KIM, Hyun Ho**
Daejeon 34122 (KR)
- **KO, Jun Seok**
Daejeon 34122 (KR)

(74) Representative: **Goddar, Heinz J.**
Boehmert & Boehmert
Anwaltspartnerschaft mbB
Pettenkoferstrasse 22
80336 München (DE)

(54) **METHOD FOR PREPARING STEAM OR HOT WATER USING WASTE HEAT OF COOLING WATER**

(57) There are provided a method for preparing steam or hot water, including: (S1) introducing process waste heat fluids supplied from a plurality of waste heat sources into each of heat exchangers configured in a number corresponding to the plurality of waste heat sources to exchange heat with cooling water; (S2) introducing the cooling water heated by heat exchange with the process waste heat fluids in each of the heat exchangers through an integrated pipe into a refrigerant evaporator, followed by heat exchange with a refrigerant to vaporize the refrigerant; (S3) compressing the vaporized refrigerant stream in a refrigerant compressor; (S4) bringing the compressed refrigerant stream into heat exchange with water in a refrigerant condenser, thereby condensing the refrigerant stream and obtaining steam or hot water; and (S5) passing the condensed refrigerant stream through a refrigerant expansion valve for depressurizing, followed by circulating into the refrigerant evaporator, and a system for performing the method.

[FIG. 3]



Processed by Luminess, 75001 PARIS (FR)

Description

[Technical Field]

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This application claims the benefit of priority to Korean Patent Application Nos. 10-2023-0050549 and 10-2024-0021815 filed on April 18, 2023 and February 15, 2024, which are hereby incorporated by reference in their entirety.

Technical Field

[0002] The present invention relates to a method for preparing steam or hot water using waste heat of cooling water, and more particularly, to a method for preparing steam or hot water by recovering waste heat of cooling water heated after exchanging heat between a plurality of waste heat sources generated in petrochemical processes and the cooling water.

[Background Art]

[0003] Petrochemical processes use a lot of energy to produce products, and the used energy is discarded or reused.

[0004] Steam used as an energy source in the petrochemical processes is generally prepared by the combustion heat of hydrocarbon fuel using a boiler (see FIG. 1), but this process involves high costs, and emits the supplied fuel into the atmosphere in the form of carbon dioxide through combustion to cause global warming.

[0005] Accordingly, in order to reduce carbon emissions and lower manufacturing costs of petrochemical products, a method for reducing steam usage in a process, a method for using waste heat, etc., are emerging.

[0006] Typically, the petrochemical products may be manufactured through processes including reaction, separation, purification, etc. When a lower portion of a column where these processes are performed is heated using steam, a high-temperature process fluid is prepared at an upper portion of the column.

[0007] Referring to FIG. 2, the high-temperature fluid prepared in the petrochemical processes may be a waste heat (WH) source, and is cooled by heat exchange with cooling water in a heat exchanger (HE) such as a condenser or a cooler to discard a large amount of heat, and the heated cooling water is introduced into a cooling tower (CT), is cooled while dissipating heat, and is then supplied back to the heat exchanger. The heat dissipated in this cooling process may be referred to as waste heat within the process.

[0008] Since the cooling tower operates to forcibly dissipate heat by bringing cooling water into contact with atmospheric air, the heat discarded from the cooling tower cannot be recovered, resulting in very large heat loss.

[0009] Therefore, there is a need for a method for effectively recovering waste heat from cooling water heated by heat exchange with high-temperature fluids (waste heat sources) prepared in various processes such as reaction, separation, and purification during manufacturing petrochemical products and reusing the recovered waste heat.

[Disclosure]

[Technical Problem]

[0010] The present invention is devised to solve the problems mentioned in the background art, and provides a method for recovering waste heat by introducing cooling water heated after exchanging heat between each of a plurality of waste heat sources generated in petrochemical processes and cooling water into a heat pump device, and preparing a large amount of steam or hot water required in the process using the recovered waste heat.

[Technical Solution]

[0011] According to an embodiment of the present invention, provided is a method for preparing steam or hot water, comprising: (S1) introducing process waste heat fluids supplied from a plurality of waste heat sources into each of heat exchangers configured in a number corresponding to the plurality of waste heat sources to exchange heat with cooling water; (S2) introducing the cooling water heated by heat exchange with the process waste heat fluids in each of the heat exchangers through an integrated pipe into a refrigerant evaporator, followed by heat exchange with a refrigerant to vaporize the refrigerant; (S3) compressing the vaporized refrigerant stream in a refrigerant compressor; (S4) bringing the compressed refrigerant stream into heat exchange with water in a refrigerant condenser, thereby condensing the refrigerant stream and obtaining steam or hot water; and (S5) passing the condensed refrigerant stream through a refrigerant expansion valve for depressurizing, followed by circulating into the refrigerant evaporator.

[0012] The integrated pipe may have a linear length of 5 to 5,000 m and may be controlled to maintain a flow velocity of 0.5 to 5 m/s.

[0013] The compressed refrigerant stream may have a temperature ranging from 90 to 200°C, and the refrigerant stream condensed by the heat exchange with water in the refrigerant condenser may have a temperature ranging from 85 to 170°C.

[0014] The steam obtained in the refrigerant condenser may be transferred to a steam compressor to be additionally compressed, and converted into high-pressure steam.

[0015] According to another embodiment of the present invention, provided is a system for preparing steam or hot water, comprising: a plurality of waste heat sources, heat exchangers configured in a number corresponding to the plurality of waste heat sources, and a heat pump device connected to the heat exchangers through an integrated pipe and a branch pipe, wherein the heat pump device includes a refrigerant evaporator, a refrigerant compressor, a refrigerant condenser, and a refrigerant expansion valve connected through a pipe, and the heated cooling water flowing out of each of the heat exchangers is combined through the integrated pipe and introduced into the refrigerant evaporator of the heat pump device, following by heat exchange with a refrigerant to vaporize the refrigerant, and then passed through the branch pipe, followed by circulating to each of the heat exchangers.

[0016] The system may include an additional steam compressor connected to the refrigerant condenser of the heat pump device.

[Advantageous Effects]

[0017] According to the present invention, a plurality of waste heat sources is each subject to heat exchange with cooling water, and each of the heated cooling water is introduced through an integrated pipe into a heat pump device for heat exchange with a refrigerant flow circulated in the heat pump device, thereby recovering waste heat of the heated cooling water. The waste heat of the cooling water is used to vaporize the refrigerant, which is subject to compression using electricity and exchanging heat with water, thereby obtaining large quantities of steam or hot water required in processes.

[0018] In addition, when the steam is obtained by using the waste heat of the cooling water recovered in the heat pump device, the compressed refrigerant and the condensed refrigerant are each controlled to exhibit a temperature so that a temperature lift is maximized, and the steam is subject to additional compression to be converted into final compressed steam having a high-temperature and a high-pressure, followed by using an energy source in various process steps. This allows to lower manufacturing costs of petrochemical products and reduce carbon emissions.

[0019] In addition, since the present invention applies on the plurality of waste heat sources generated in various petrochemical processes, it is possible to recover waste heat from a plurality (e.g., 10 to 100) of cooling water heat exchangers in a petrochemical plant and it is possible for the waste heat recovery to be accomplished in a single heat pump device through the integrated pipe. In particular, by controlling a flow velocity of the integrated pipe to be in a predetermined range to maintain a uniform mixing state of the heated cooling water, it is possible to implement cost reduction, minimization of maintenance, operation stabilization, etc., through simplification and operation efficiency of steam preparation equipment.

[Brief Description of the Drawings]

[0020]

FIG. 1 is a diagram schematically illustrating a steam generation process using a boiler.

FIG. 2 is a diagram schematically illustrating a process of exchanging heat between waste heat sources prepared in various petrochemical processes with cooling water and then cooling heated cooling water in a cooling tower.

FIG. 3 is a diagram illustrating a process of heat exchange between each of the plurality of waste heat sources and the cooling water and then cooling the heated cooling water in the heat pump device to recover waste heat, and preparing steam or hot water required in the process, according to the present invention.

FIG. 4 is a diagram illustrating a process of obtaining high-pressure steam by additionally connecting a steam compressor to a refrigerant condenser of the heat pump device according to the present invention.

FIG. 5 is a diagram illustrating a process of exchanging heat between each of the plurality of waste heat sources and the cooling water and then cooling the heated cooling water in a cooling tower in Comparative Example.

[Best Mode]

[0021] Terms and words used in the present specification and claims are not to be construed as a general or dictionary meaning but are to be construed as meaning and concepts meeting the technical ideas of the present invention based on a principle that the inventors can appropriately define the concepts of terms in order to describe their own inventions in best mode.

[0022] A term "including" or "containing" used herein concretely indicates specific properties, regions, integer numbers, steps, operations, elements, or components, and is not to exclude presence or addition of other specific properties, regions, integer numbers, steps, operations, elements, components, or a group thereof.

[0023] The term 'stream' used herein may mean a flow of a fluid in a process, and may also mean a fluid itself flowing in a pipe. Specifically, the stream may mean both the fluid itself and the flow of the fluid flowing within the pipe connecting each device. In addition, the fluid may include any at least one components of a gas, a liquid, and a solid.

[0024] An embodiment of the present invention relates to a method for preparing steam or hot water by heat exchange between a plurality of waste heat sources and cooling water and then recovering waste heat of the heated cooling water. Specifically, the method includes the steps of (s1) heat exchange between a plurality of process waste heat fluids and the cooling water, (s2) integrating the cooling water heated by the heat exchange, followed by heat exchange with a refrigerant to vaporize the refrigerant, (s3) compressing the vaporized refrigerant stream, (s4) heat exchange between the compressed refrigerant stream and water to condense the refrigerant stream and obtain the steam or hot water, and (S5) depressurizing the condensed refrigerant stream.

[0025] Hereinafter, the method for preparing steam or hot water will be described step by step in detail with reference to the attached drawings.

[0026] Referring to FIG. 3, the method for preparing steam or hot water by recovering the waste heat of cooling water according to the present invention may be performed using a system for preparing steam or hot water that includes a plurality of waste heat sources 100, heat exchangers 200 configured in a number corresponding to the plurality of waste heat sources, and a heat pump device 300 connected to the heat exchanger through an integrated pipe and a branch pipe.

[0027] The plurality of waste heat sources 100 may include high-temperature process waste heat fluids generated in various processes such as reaction, separation, and purification when manufacturing petrochemical products. The temperature of the high-temperature process waste heat fluid may vary depending on conditions of each process. For example, it may be approximately in the range of 20 to 250°C, specifically 30 to 150°C.

[0028] If such process waste heat fluids are wasted without separate heat recovery, it is undesirable in view of energy perspectives. Accordingly, it is necessary to recover heat from the waste heat source 100, that is, the high-temperature process waste heat fluid and use the recovered heat in other processes requiring heat, by reducing energy usage throughout the process.

[0029] To this end, the process waste heat fluids (WH1, WH2, WH3, ...) may be supplied to heat exchangers (HE1, HE2, HE3, ...) using cooling water. The process waste heat fluids may be subject to heat exchange with the cooling water in the heat exchangers (HE1, HE2, HE3, ...), so that the heat of the process waste heat fluids may be transferred to the cooling water. Furthermore, the cooling water whose temperature, which has been lifted by heat received, may be supplied to a refrigerant evaporator described later and used as a heat source for vaporization of the refrigerant.

[0030] Specifically, since the process waste heat fluids (WH1, WH2, WH3, ...) may each have different fluid properties such as components and temperature, it may not be appropriate to directly supply the process waste heat fluids to the refrigerant evaporator. For the operation stabilization and reliability of the refrigerant evaporator, each of the process waste heat fluids is first heat-exchanged with the cooling water in the heat exchanger (sometimes referred to as a cooling water heat exchanger), and then, it may be preferable to supply the high-temperature cooling water from the heat exchanger to the refrigerant evaporator.

[0031] In an embodiment of the present invention, the heat exchanger 200 is connected to the plurality of waste heat sources 100 and may be configured in a number (HE1, HE2, HE3, ...) corresponding to the process waste heat fluids (WH1, WH2, WH3, ...). In such a heat exchanger, the cooling water is circulated to cool or condense the waste heat sources 100.

[0032] Generally, in a petrochemical plant, a plurality of cooling water heat exchangers, for example, about 10 to 100 cooling water heat exchangers operate to cool or condense the high-temperature process fluids prepared in various processes. The present invention is to utilize the plurality of cooling water heat exchangers simultaneously. For this, the cooling water heat exchangers may be each individually connected to each of the plurality of waste heat sources to cool or condense the high-temperature process fluids and recover heat therefrom, while heating the cooling water circulated in each heat exchanger by the recovered heat, and then the heated cooling water may be supplied to one refrigerant evaporator, thereby processing a large amount of process waste heat fluids simultaneously.

[0033] The heat exchangers may include a cooler or condenser commonly used in the petrochemical processes. The heat exchangers applicable to the present invention may be a general shell and tube type, and may also be a plate type or falling film evaporator type to increase heat exchange efficiency, but is not limited thereto.

[0034] In an embodiment of the present invention, each of the heat exchangers (HE1, HE2, HE3, ...) may be supplied and circulated with cooling water of 10 to 50°C, specifically 20 to 40°C under conditions of a pressure of 1 to 20 bar, specifically a pressure of 2 to 10 bar, and a flow rate of 10 to 1,000,0000 tons/hr, specifically 20 to 100,000 tons/hr.

[0035] Specifically, when the high-temperature (for example, 20 to 250°C) process waste heat fluids (WH1, WH2, WH3, ..) supplied from the plurality of waste heat sources 100 are introduced into each heat exchanger (HE1, HE2, HE3, ...) in which the cooling water is circulated, the cooling water may absorb heat from the process waste heat fluids and lift its temperature through mutual heat exchange. In this case, it is advantageous to adjust the temperature lift range of the cooling water to 13 to 60°C, for example, 15 to 50°C to maintain the temperature difference with the process waste heat to an appropriate range.

[0036] Meanwhile, the flow rates of the process waste heat fluids introduced into each of the heat exchangers (HE1, HE2, HE3, ...) are not particularly limited, but may be, for example, 0.1 to 100,000 tons/hr, specifically 0.5 to 50,000 tons/hr or 1 to 40,000 tons/hr. The process waste heat fluids that are heat-exchanged with cooling water in each of the heat exchangers (HE1, HE2, HE3, ...) may flow out of each heat exchanger at a temperature lower than the initial temperature, for example, in the range of 15 to 200°C.

[0037] Thereafter, the cooling water heated in each of the heat exchangers (HE1, HE2, HE3, ...) is cooled after supplying heat to the refrigerant evaporator, and then needs to be circulated to the heat exchanger (cooling water heat exchanger) in order to cool or condense the high-temperature process waste heat fluid in the process (i.e., to recover the heat of the process waste heat fluid).

[0038] In the present invention, the cooling water heated in each of the heat exchangers (HE1, HE2, HE3, ...) is combined in one integrated pipe 10, and then the cooling water stream combined in the integrated pipe 10 may be supplied to the heat pump device 300, specifically, the refrigerant evaporator (EV).

[0039] If each cooling water stream is directly supplied to the refrigerant evaporator (EV) provided in the heat pump device 300, each cooling water stream heated in each heat exchanger (HE1, HE2, HE3, ...) may be not uniform in temperature and flow rate, which may hinder stable operation of the refrigerant evaporator (EV) and excessively increase equipment cost for solving such problem of the refrigerant evaporator (EV). Furthermore, the unstable operation of the refrigerant evaporator (EV) may cause overcooling or undercooling of the refrigerant, which may also hinder the operation stabilization of other equipment provided in the heat pump device 300, such as the refrigerant compressor (CP).

[0040] According to an embodiment of the present invention, the heated cooling water streams are each combined in one integrated pipe 10 and supplied, thereby ensuring the uniformity of the flow rate and temperature of each of the heated cooling water streams. Specifically, the integrated pipe 10 may be a header type pipe with caps at both ends to collect the heated cooling water stream flowing out of each of the heat exchangers (HE1, HE2, HE3, ...) configured in parallel. In order for the cooling water stream to be supplied to the refrigerant evaporator (EV) of the heat pump device 300 while maintaining the uniform mixing state, it is necessary to design the length of the integrated pipe and the flow velocity of the working fluid to an appropriate range.

[0041] Specifically, the linear length of the integrated pipe 10 may be 5 to 5,000 m, specifically 10 to 1,000 m. If the length of the integrated pipe is less than 5 m, as the heat mixing of the heated cooling water becomes non-uniform, a refrigerant evaporation rate changes in the refrigerant evaporator (EV) of the heat pump device 300 due to the heat exchange, and the surging or cavitation phenomenon may occur in the refrigerant compressor (CP) at the rear stage, resulting in making the driving itself impossible. If the length of the integrated pipe exceeds 5,000 m, heat loss may occur to reduce the amount of waste heat or increase the pipe differential pressure, resulting in the increase in power.

[0042] In addition, the flow velocity of the integrated pipe 10 may range from 0.5 to 5 m/s, specifically 1 to 3 m/s. If the flow velocity of the integrated pipe is less than 0.5 m/s, the heat mixing efficiency of the heated cooling water may decrease. If the flow velocity of the integrated pipe exceeds 5 m/s, the erosion may occur within the pipe.

[0043] By applying the integrated pipe 10 as described above, it is possible to implement the cost reduction, the minimization of maintenance, and the stabilization of operation through the simplification and operation efficiency of the steam preparation equipment.

[0044] Meanwhile, if the waste heat of the cooling water is recovered by connecting the heat pump devices to each cooling water heat-exchanged per a single waste heat source, it may need a plurality of heat pump devices for the heat exchangers corresponding to the plurality of waste heat sources, so it is difficult to obtain an economic effect of replacing the cooling tower which is a means of cooling the heated cooling water in the conventional method.

[0045] In the present invention, the plurality of cooling water streams is heated by the heat exchange with the plurality of waste heat sources, following being combined in the integrated pipe and then supplied to the heat pump devices, thereby obtaining advantages such as the simplification of control and operation, the reduced number of abnormal operations, and the increased replacement cycle, compared to operating the plurality of heat pump devices.

[0046] In addition, if the heat pump device is connected to each cooling water heat-exchanged with a single waste heat source, there may be a waste heat source that cannot be recovered due to limitations of small-capacity equipment. However, in the present invention, even trace amounts of waste heat may be recovered by supplying the plurality of heated cooling water streams to the heat pump device through the integrated pipe.

[0047] Additionally, if the plurality of heat pump devices each individually operates, it may be difficult to control the material balance of the entire facility. However, the present invention can control a more efficient material balance by applying the single heat pump device through the integrated pipe, thereby improving the operation stabilization and reducing the number of maintenance times.

[0048] The heat pump device 300 used in the present invention performs a cycle of transferring a low-temperature heat source to a high temperature or transferring a high-temperature heat source to a low temperature using the evaporation or condensation heat of the refrigerant, and the members of the refrigerant evaporator (EV), the refrigerant compressor (CP), the refrigerant condenser (CD), and the refrigerant expansion valve (EP valve) are connected through a pipe so that the refrigerant may circulate.

[0049] The refrigerant evaporator (EV) is a member that vaporizes and evaporates the refrigerant by heat exchange between the high-temperature fluid and the refrigerant, and each of the refrigerant evaporators applicable to the present invention may be a general shell and tube type, and may also be a plate type or falling film evaporator type to increase heat exchange efficiency, but is not limited thereto.

[0050] A low-temperature and low-pressure liquid refrigerant, for example, a refrigerant having a pressure of 0.5 to 40 bar or 1 to 20 bar and a temperature of 10 to 60°C or 15 to 50°C, respectively, may be introduced into the refrigerant evaporator (EV). When the heated refrigerant streams which flow out of each heat exchanger (HE1, HE2, HE3, ...) and are combined in the integrated pipe 10 are introduced into the refrigerant evaporator (EV) through which the low-temperature and low-pressure refrigerant flows, the refrigerant is vaporized by the heat exchange.

[0051] That is, when the mixed stream of cooling water heated to the range of 13 to 60°C is introduced into the refrigerant evaporator (EV), the refrigerant absorbs heat through the mutual heat exchange and may be converted into a gaseous stream with a relatively high temperature. Meanwhile, the heated cooling water supplies heat in the refrigerant evaporator, thereby being cooled to the range of 10 to 50°C and then circulated to each of the heat exchangers (HE1, HE2, HE3, ...) through a plurality of branch pipes connected to the pipe 20.

[0052] If necessary, the pump for effective circulation of cooling water may be installed at a rear end of the refrigerant evaporator (EV) through which the heated cooling water is introduced and flows.

[0053] In an embodiment of the present invention, the total flow rate of the refrigerant introduced into the refrigerant evaporator (EV) through the integrated pipe 10 may be 10 to 1,000 tons/hr, for example, 20 to 500 tons/hr or 30 to 400 tons/hr, and the flow rate of the mixed stream of the heated cooling water introduced into the refrigerant evaporator (EV) may be 0.1 to 100,000 tons/hr, for example, 0.5 to 50,000 tons/hr or 1 to 40,000 tons/hr, but is not limited thereto.

[0054] Next, the refrigerant stream vaporized in the refrigerant evaporator (EV) is introduced into the refrigerant compressor (CP), and compressed by being supplied with electrical energy to increase its pressure. In this case, the temperature of the gaseous refrigerant stream may also increase in proportion to the amount of electrical energy supplied.

[0055] When the refrigerant compressor (CP) is a device capable of compressing a gaseous flow, various devices known in the art can be used without limitation. For example, a turbo-type compressor capable of compressing a large capacity may be used. In addition, the refrigerant compressor (CP) may be applied as one or as a plurality of refrigerant compressors connected in series depending on the capacity of the introduced refrigerant stream.

[0056] This refrigerant compressor (CP) may increase the pressure of the gaseous refrigerant stream introduced through the refrigerant evaporator (EV) by 1.2 to 5 times or 1.4 to 4.5 times. For example, the pressure of the refrigerant stream passing through the compressor CP may be 0.5 to 50 bar or 1 to 40 bar, and when the compression of the gaseous refrigerant stream is performed in the above range, it is easy to implement the type selection, design and manufacture of the compressor.

[0057] In addition, the temperature of the refrigerant stream compressed through the compressor CP may be adjusted to a range of 90 to 200°C or 105 to 180°C. When the temperature of the compressed refrigerant stream is less than 90°C, a problem may occur in which the heat exchange efficiency with water in the refrigerant condenser at the rear stage rapidly decreases, and when the temperature of the compressed refrigerant stream exceeds 200°C, the carbonization of the refrigerant or compressor lubricating oil may be caused, or the excessive increase in the refrigerant vapor pressure may make the manufacture of equipment impossible or cause the incomplete operation.

[0058] Thereafter, the high-temperature/high-pressure refrigerant stream flowing out of the compressor is introduced into the refrigerant condenser (CD), and the heat exchange may be performed between the high-temperature/high-pressure refrigerant stream compressed in the refrigerant condenser (CD) and water supplied from the outside, thereby condensing the refrigerant stream and obtaining the steam or hot water.

[0059] The refrigerant condenser (CD) applicable to the present invention may be a general shell and tube type, and may also be a plate type or falling film evaporator type to increase the heat exchange efficiency, but is not limited thereto. In addition, the refrigerant condenser (CD) may be applied as one or as a plurality of refrigerant condensers connected in series depending on the capacity of the introduced refrigerant stream.

[0060] In the refrigerant condenser (CD), the refrigerant may be condensed from the high-temperature/high-pressure gaseous stream to the low-temperature liquid stream as the refrigerant is heat-exchanged with water to release heat, and water supplied from the outside may absorb the heat generated by condensing the refrigerant to be converted into the high-temperature hot water or steam.

[0061] More specifically, in the present invention, when the gaseous refrigerant stream obtained through the waste heat recovery of the cooling water heated in the heat pump device is compressed by being supplied with electricity, and then the compressed refrigerant stream is circulated to the refrigerant condenser (CD) to perform the heat exchange with water, the hot water or steam may be selectively obtained by changing the discharge pressure of water passing through the refrigerant condenser (CD).

[0062] For example, after water is supplied with heat from the refrigerant condenser (CD), when an outlet pressure of the pipe through which the water is discharged is adjusted to be higher than a vapor pressure through a valve, liquid hot water at a temperature of about 85 to 180°C, specifically 100 to 150°C may be prepared by the heat exchange between the compressed refrigerant stream and the water. In this case, when the discharge pressure of water passing through the refrigerant condenser is adjusted based on the vapor pressure, the vapor pressure may be determined according to the temperature of the discharged water. Therefore, when the temperature of water discharged from the condenser is 90°C, the outlet pressure of the pipe may be set to 0.7 bar or more, when the temperature of the discharged water is 100°C, the output pressure of the pipe may be set to 1 bar or more, and when the temperature of the discharged water is 150°C, the outlet pressure of the pipe may be adjusted to 4.8 bar or more.

[0063] The hot water discharged from the refrigerant condenser (CD) may be used as high-temperature process water (e.g., boiler feed water or heat source water for emulsion polymerization) in the petrochemical processes, and since this hot water preparation uses the waste heat and electricity, it is very efficient in terms of energy consumption compared to the existing method for preparing hot water by mixing steam with common industrial water.

[0064] Meanwhile, when the outlet pressure of the pipe through which water supplied with heat through the refrigerant condenser (CD) is discharged is adjusted to less than the vapor pressure, hydrogen bonds of water molecules may be broken by the heat exchange between the compressed refrigerant stream and water to prepare a gaseous steam. As described above, the vapor pressure that is the standard for the output pressure of the pipe may be determined depending on the temperature of the discharged water.

[0065] In addition, in the above process, the hot water and steam may flow out of the refrigerant condenser (CD) in the mixed state.

[0066] In an embodiment of the present invention, the refrigerant stream condensed by the heat exchange with water in the refrigerant condenser (CD) is preferably maintained at a saturation temperature of 85 to 170°C at a high pressure of 3 to 50 bar or 6 to 40 bar. If the temperature of the condensed refrigerant stream is less than 85°C, the pressure of water in the refrigerant condenser (CD) may be lower than the atmospheric pressure, so the steam or hot water prepared by the heat exchange may be contaminated and cannot be used in the process. If the temperature of the condensed refrigerant stream exceeds 170°C, the carbonization of the refrigerant or the compressor lubricating oil may occur, or the excessive increase in the refrigerant vapor pressure may make the manufacture of the facility impossible or cause the incomplete operation.

[0067] In this way, in order to ensure the temperature of the condensed refrigerant stream at 85°C or higher, it is advantageous to adjust the critical temperature of the refrigerant to 100°C or higher. The refrigerant critical temperature is a unique physical property value given to each material thermodynamically, and physically refers to the maximum temperature at which the gas phase and liquid phase may be distinguished. The heat exchange potential of the refrigerant may be maintained when this critical temperature differs from the temperature of the condensed refrigerant stream by 15°C or higher. If the heat exchange potential in the refrigerant condenser decreases and the temperature of the condensed refrigerant stream is less than 85°C, the temperature lift for obtaining steam or hot water is not sufficient, resulting in malfunction problems such as compressor surge.

[0068] In the present invention, the refrigerant may be selected from various types known in the art, without any particular restrictions, if it satisfies the critical temperature conditions of the refrigerant as described above. For example, one or more refrigerants selected from hydrofluorocarbon (HFC) series R245fa, R134a, R1234ze and R1234yf, and hydrofluoroolefin (HFO) series R1234ze(E), R1234ze(Z), and R1233zd(E) may be used.

[0069] In addition, the pressure of the condensed refrigerant stream may be maintained at a high pressure of 3 to 50 bar or 6 to 40 bar, but is not limited thereto.

[0070] Meanwhile, the water supplied to the refrigerant condenser (CD) is preferably pure water in which ions and oxygen are removed, and it may be introduced under the conditions of a temperature of 10 to 100°C or 20 to 95°C and a pressure of 1 to 20 bar or 1.5 to 10 bar. In addition, the flow rate of water supplied to the refrigerant condenser (CD) may be 1 to 100 tons/hr, for example, 2 to 80 tons/hr or 3 to 50 tons/hr, but is not limited thereto.

[0071] The steam prepared by the heat exchange with the high-temperature/high-pressure gaseous refrigerant stream in the refrigerant condenser (CD) or the mixed state of the steam and hot water may represent a temperature of 95 to 200°C or 100 to 180°C and a pressure of 0.5 to 16 bar or 1 to 10 bar.

[0072] Thereafter, the liquid refrigerant stream flowing out of the refrigerant condenser (CD) may be depressurized by passing through the refrigerant expansion valve (EP valve), and the refrigerant stream passing through the refrigerant expansion valve may be circulated to the refrigerant evaporator (EV).

[0073] The refrigerant expansion valve (EP valve) is a device that lowers the pressure and temperature of the refrigerant stream liquefied in the condenser so that the refrigerant stream may easily evaporate in the evaporator and controls the flow rate of the refrigerant stream. That is, the liquid refrigerant stream that has passed through the expansion valve may be evaporated even at a relatively low temperature when it is introduced into the refrigerant evaporator again as both the pressure and boiling point are lowered.

[0074] For example, the refrigerant stream passing through the expansion valve may be in the form of a low-temperature/low-pressure liquid phase indicating a pressure of 0.5 to 30 bar or 1 to 20 bar and a temperature of 10 to 60°C or 20 to 50°C, respectively.

[0075] The expansion valve (EP valve) applicable to the present invention may be formed in various structures, such as an electric expansion valve, a thermostatic expansion valve, and an automatic expansion valve. In addition, the expansion valve may be applied as one or as a plurality of expansion valves connected in series depending on the capacity of the introduced refrigerant stream.

[0076] Meanwhile, as the steam flowing out of the refrigerant condenser (CD) has a low pressure of 0.5 to 16 bar, it may be difficult to use the steam directly in the process, so it is preferable to convert the steam into the high-pressure steam by performing the additional compression.

[0077] As illustrated in FIG. 4, a steam compressor (S-CP) may be connected to the refrigerant condenser (CD) of the heat pump device 300, and the steam flowing out of the refrigerant condenser (CD) may be introduced into the steam compressor (S-CP) to increase the pressure of the final steam to a range of 2 to 60 bar or 3 to 30 bar.

[0078] Similar to the refrigerant compressor (CP) described above, the steam compressor (S-CP) may use a turbo-type compressor capable of handling large capacities, may be supplied with electrical energy for compression of water molecules, and may increase the temperature of the steam in proportion to the amount of electrical energy supplied.

[0079] In this case, since the heat exchange efficiency of superheated steam decreases when input into the heat exchanger in the process, make-up water may be supplied to prepare saturated steam. The make-up water supplied to the steam compressor (S-CP) is preferably pure water in which ions and oxygen are removed, and it may be input to the process by joining the saturated steam while lowering the superheat of the steam. The flow rate of the make-up water may be 0.1 to 30 tons/hr or 1 to 20 tons/hr, but is not limited thereto.

[0080] The high-pressure steam flowing out of the steam compressor (S-CP) may finally have a temperature of 140 to 280°C or 150 to 240°C.

[0081] As described above, according to the present invention, a plurality of waste heat sources is each subject to heat exchange with cooling water, and each of the heated cooling water is introduced through an integrated pipe into a heat pump device for heat exchange with a refrigerant flow circulated in the heat pump device, thereby recovering waste heat of the heated cooling water. The waste heat of the cooling water is used to vaporize the refrigerant, which is subject to compression using electricity and exchanging heat with water, thereby obtaining large quantities of steam or hot water required in processes. For example, the final amount of steam prepared according to the present invention may be 1 to 120 tons/hr or 6 to 100 tons/hr.

[0082] The steam generation heat according to the present invention may be defined by Equation 1 below, and the coefficient of performance COP of the system applied to the method for preparing steam or hot water of the present invention may be expressed by Equation 2 below.

Steam generation heat = Waste heat + Supplied power (power used for refrigerant compression and steam compression) [Equation 1]

[Equation 2]

COP = Steam generation heat / supplied power

[0083] The coefficient of performance (COP) according to Equation 3 above is defined as the steam generation heat (the amount of heat absorbed by water) compared to the electric energy input to the refrigerant compressor and the steam compressor. For example, when the COP value is 1.5, this means that the heating value that is 1.5 times that of the input electrical energy is obtained.

[0084] The steam prepared by the method according to the present invention satisfies the value of COP calculated through Equation 3 that is 1.3 or more, specifically 1.5 or more, ensuring economic efficiency compared to the input electric energy.

[0085] According to the present invention, steam prepared in large quantities through waste heat recovery by connecting the plurality of waste heat sources to one heat pump device may be stored and distributed and supplied to local user sources throughout the process.

[0086] Hereinafter, the present invention will be described in more detail with through Examples. However, the following examples are for illustrating the present invention, and it is clear to those skilled in the art that various changes and modifications are possible within the scope and spirit of the present invention, and the scope of the present invention is not limited only thereto.

Example 1:

[0087] As illustrated in FIG. 3, waste heat was recovered and steam/hot water was prepared using a system which includes three waste heat sources 100, heat exchangers 200 and a single heat pump device 300 connected through an integrated pipe 10 to the heat exchangers.

(Step 1)

[0088] First, process waste heat fluids WH1, WH2, and WH3 in a gaseous state (75°C and 5 bar) were individually supplied to each of the three waste heat sources 100 at a flow rate of 52 tons/hr, and the heat exchange was performed by introducing the plurality of process waste heat fluids into each of the heat exchangers HE1, HE2, and HE3 in which the cooling water at 30°C was circulated at a pressure of 5 bar. After the heat exchange, the process waste heat fluids WH1, WH2, and WH3 in each of the heat exchangers HE1, HE2, and HE3 emitted heat and flowed out in the liquid state at 65°C and 4 bar, and the cooling water (40°C and 5 bar) heated by the heat absorption was flowed out.

(Step 2)

[0089] The cooling water (40°C and 5 bar) streams heated in the three heat exchangers HE1, HE2, and HE3 were combined in the integrated pipe 10 (straight length 50 m and flow velocity 1 m/s), and then supplied to the refrigerant evaporator (EV) of the heat pump device 300.

[0090] The heat pump device 300 includes the refrigerant evaporator (EV), the refrigerant compressor (CP), the refrigerant condenser (CD), and the refrigerant expansion valve EP valve, and in the refrigerant evaporator (EV), the refrigerant (trans-1-chloro-3,3,3-trifluoropropene, R1233zd(E)) in the liquid state (25°C and 1.3 bar) was circulated at a flow rate of 310 tons/hr, and heat-exchanged with the mixed stream (40°C) of the heated cooling water supplied through the integrated pipe 10.

[0091] After the heat exchange, the mixed stream of the cooling water in the refrigerant evaporator (EV) was cooled to 30°C and then circulated to each heat exchanger HE1, HE2, and HE3 through the plurality of branch pipes connected to the pipe 20, and the refrigerant was vaporized by the heat absorption and flowed out in the gaseous state of 25°C and 1.3 bar.

(Step 3)

[0092] After the gaseous refrigerant stream was introduced into the refrigerant compressor (CP), the compression was performed under a power of 9.9 Gcal/h to obtain a refrigerant stream compressed in a gaseous state of 128°C and 16 bar.

(Step 4)

[0093] The compressed refrigerant stream (128°C and 16 bar) was introduced into a refrigerant condenser (CD), and water (20°C and 5 bar) was supplied to the refrigerant condenser (CD) at a flow rate of 38 tons/hr to perform the heat exchange. In this case, the outlet pressure of the pipe through which water passes through the refrigerant condenser (CD), that is, the discharge pressure of water was adjusted to 2 bar using a pressure control valve provided on the pipe so that the output pressure of the pipe is maintained less than the vapor pressure (2.3 bar) at the temperature of the heat-exchanged water (124°C). In this way, the heat-exchanged water was obtained as steam 38 tons/hr at 124°C and 2 bar, and the refrigerant stream was condensed and flowed out as a liquid at 120°C and 16 bar.

(Step 5)

[0094] The condensed refrigerant stream (120°C and 16 bar) passed through the expansion valve (EP valve) to obtain the liquid refrigerant stream at 25°C and 1.3 bar, and then circulated to the refrigerant evaporator (EV).

Example 2:

[0095] The procedure of Example 1 was performed except that, in step 4, water (20°C and 5 bar) was supplied to the refrigerant condenser (CD) at a flow rate of 240 ton/hr, and the outlet pressure of the supply water pipe was adjusted to 2.5 bar so that the outlet pressure is maintained at the vapor pressure (2.3 bar) or higher at the temperature (124°C) of the heat-exchanged water, so 240 tons/hr of hot water at 124°C and 2.5 bar was obtaind from the heat exchange between the compressed refrigerant and water (20°C and 1 bar).

Example 3:

[0096] The procedure of Example 1 was performed except that the steam obtained in the refrigerant condenser (CD) was transferred to the steam compressor (S-CP) to perform additional compression.

[0097] The compression was performed by supplying water (20°C and 5 bar) at a flow rate of 38 tons/hr under a power of 4.0 Gcal/h, so finally the steam of 200°C and 13 bar was prepared in a rate of 45 tons/hr. As the additional water was supplied to cool the overheated steam in the steam compressor, the amount of finally prepared steam increased compared to the amount of water initially supplied.

[0098] For the finally prepared steam, the steam generation heat was calculated according to Equation 1 below, and a coefficient of performance (COP) was calculated according to Equation 2 below.

Steam (or hot water) generation heat = Waste heat + Supplied power (power used for refrigerant compression and steam compression) [Equation 1]

COP = Steam (or hot water) generation heat/ supplied power [Equation 2]

Example 4:

[0099] The procedure of Example 1 was performed except that the gaseous refrigerant stream was compressed in the refrigerant compressor (CP) under a power of 6.9 Gcal/h to obtain the refrigerant stream compressed into the gaseous state at 98°C and 7.8 bar, and then the compressed refrigerant stream was heat exchanged with 27 tons/hr of water (20°C and 1 bar) in the refrigerant condenser (CD) to prepare steam of 78°C and 0.4 bar and the condensed refrigerant stream of 87°C and 7.8 bar flowed out and transferred to the expansion valve (EP valve).

[0100] The compression was performed by transferring the steam obtained in the refrigerant condenser (CD) to a steam compressor (S-CP), and supplying water (20°C and 1 bar) at a flow rate of 30 tons/hr under a power of 3.5 Gcal/h, so steam at 149°C and 3.9 bar was finally prepared in an amount of 35 tons/hr.

Example 5:

[0101] The procedure of Example 1 was performed except that the flow velocity of the integrated pipe was changed to 0.3m/s, and the steam obtained in the refrigerant condenser (CD) was transferred to the steam compressor (S-CP) with supplying water (20°C and 5bar) at a flow rate of 38tons/hr under a power of 4.0Gcal/h to perform additional compression.

Example 6:

[0102] The procedure of Example 1 was performed except that the flow velocity of the integrated pipe was changed to 6m/s, and the steam obtained in the refrigerant condenser (CD) was transferred to the steam compressor (S-CP) with supplying water (20°C and 5bar) at a flow rate of 38tons/hr under a power of 4.0Gcal/h to perform additional compression.

Comparative Example 1:

[0103] As the process illustrated in FIG. 5, three heat sources 100 including process waste heat fluids WH1, WH2, and WH3 were supplied to the heat exchangers HE1, HE2, and HE3, respectively, to perform heat exchange with cooling water under the same conditions as in Example 1, and then, a mixed stream of heated cooling water (40°C and 5 bar) flowing out of each of the heat exchangers was supplied to a cooling tower (CT) and cooled.

[0104] Specifically, the cooling tower is an open forced-air counter-flow type commonly used in the field, and supplied the mixed stream of the heated cooling water to a filler through a spray nozzle installed at an upper portion of the cooling tower, and the air introduced by an upper fan of the cooling tower came into contact with cooling water in a counter-current contact on the filler, and thus dissipated into the atmosphere while retaining moisture equivalent to the amount of saturated steam. In this process, the temperature of the cooling water was reduced by evaporation latent heat, and the cooling water is collected in a lower water tank, and then circulated to each of the heat exchangers HE1, HE2, and HE3.

[0105] In other words, the mixed stream of the cooling water heated in the cooling tower could not be recovered since the heat was forcibly dissipated through contact with air.

[0106] The results of the waste heat recovery from the heated cooling water in the above Examples and Comparative Examples were shown in Table 1 below.

[Table 1]

	Heated cooling water (T/P)	Integr ated pipe (flow veloci ty)	Compressed refrigeran t (T/P)	Condensed refrigerant (T/P)	Steam compres sion	Final product from waste heat recovery
Ex. 1	40°C/5bar	1m/s	128°C/16bar	120°C/16bar	X	Steam (124'C/2bar/ COP 2.5)
Ex. 2	40°C/5bar	1m/s	128°C/16bar	120°C/16bar	X	Hot water (124°C/2.5ba r/COP 2.5)
Ex. 3	40°C/5bar	1m/s	128°C/16bar	120°C/16bar	○	Steam (200°C/13bar /COP 2.1)
Ex. 4	40°C/5bar	1m/s	98°C/7.8bar	87°C/7.8bar	○	Steam (149°C/3.9ba r/COP 2.4)
Ex. 5	40°C/5bar	0.3m/s	115°C/9.3ba r	95°C/9.3bar	○	Steam (167°C/6.2ba r/COP 2.0)
Ex. 6	40°C/5bar	6m/s	118°C/9.1ba r	94°C/9.1bar	○	Steam (157°C/6.0ba r/COP 1.9)
Com. Ex. 1	40°C/5bar	-	-	-	-	No waste heat re-covery

[0107] As can be seen in Table 1, in comparative example 1, it was impossible to recover the cooling water heated by the heat exchange with the plurality of waste heat sources since the heat was forcibly dissipated through the contact with air in the cooling tower (CT). On the other hand, in examples 1 to 6, each of the plurality of waste heat sources was heat-exchanged with the cooling water and then the heated cooling water was introduced into the heat pump device through the integrated pipe, the waste heat of the heated cooling water could be recovered by heat exchange with the refrigerant flow circulated in the heat pump device, and the steam or hot water was prepared using the recovered waste heat.

[0108] In particular, example 3 satisfied the flow velocity of the integrated pipe in the range of 0.5 to 5 m/s to maintain the uniform mixing of the heated cooling water stream, and controlled the temperature of the refrigerant condensed in the refrigerant compressor to 85°C or higher to maintain the temperature of the steam obtained in the refrigerant condenser to be 85°C or higher and then performed the additional steam compression, so the difference between the initial waste heat temperature and the finally prepared steam temperature, that is, the temperature lift was the highest.

[0109] Meanwhile, Example 4 satisfied the flow velocity of the integrated pipe in the range of more than 0.5 m/s to 5 m/s, but as the temperature of the condensed refrigerant after the compression was low at 75°C, the obtained steam was low at 78°C, so the temperature lift was insufficient even after the steam compression. In addition, the steam was contaminated due to air leakage caused by the low pressure of the steam to cause the corrosion and erosion of the pipe, and as a result, the temperature and pressure of the final prepared steam decreased compared to Example 3.

[0110] In the case of Example 5, as the flow velocity of the integrated pipe was low at 0.3m/s, the heat mixing efficiency of the refrigerant vaporized at the front end of the refrigerant compressor decreased, resulting in the large change in the temperature and pressure of the refrigerant. As a result, a surging and cavitation phenomenon occurred in the refrigerant compressor and steam compressor, and the amount of steam changed at a rear end of the steam compressor, resulting in a pressure change. As a result, the temperature, pressure, and coefficient of performance (COP) of the final prepared steam decreased compared to Example 3.

[0111] In the case of Example 6, as the flow velocity of the integrated pipe was high to 6m/s, the erosion and vibration occurred within the refrigerant pipe at the front end of the refrigerant compressor. As a result, since it was difficult to operate the refrigerant pipe for a long time, maintenance or pipe replacement was required, and eroded foreign matter caused damage to rotating members in the compressor and noise due to vibration. As a result, the temperature, pressure, and coefficient of performance (COP) of the final prepared steam decreased compared to Example 3.

[Description of reference numerals]

[0112]

100: Plurality of waste heat sources including process waste heat fluids (WH1, WH2, WH3, ...)
200: Plurality of heat exchangers (HE1, HE2, HE3, ...)
300: Heat pump device
EV: Refrigerant evaporator
CP: Refrigerant compressor
CD: Refrigerant condenser
EP valve: Refrigerant expansion valve
10, 20: Integrated pipe
S-CP: Steam compressor

Claims

1. A method for preparing steam or hot water, comprising:

(S1) introducing process waste heat fluids supplied from a plurality of waste heat sources into each of heat exchangers configured in a number corresponding to the plurality of waste heat sources to exchange heat with cooling water;
(S2) introducing the cooling water heated by heat exchange with the process waste heat fluids in each of the heat exchangers through an integrated pipe into a refrigerant evaporator, followed by heat exchange with a refrigerant to vaporize the refrigerant;
(S3) compressing a vaporized refrigerant stream in a refrigerant compressor;
(S4) bringing a compressed refrigerant stream into heat exchange with water in a refrigerant condenser, thereby condensing the refrigerant stream and obtaining steam or hot water; and
(S5) passing a condensed refrigerant stream through a refrigerant expansion valve for depressurizing, followed by circulating into the refrigerant evaporator.

2. The method of claim 1, wherein the heated cooling water is cooled by the heat exchange in the refrigerant evaporator and then branched out, followed by circulating to each heat exchangers used in step (S1).

3. The method of claim 1, wherein in step (S1), a temperature of the cooling water introduced into each heat exchanger ranges from 10 to 50°C, and the cooling water is heated to a temperature ranging from 13 to 60°C by the heat exchange.

4. The method of claim 1, wherein the integrated pipe has a linear length of 5 to 5,000 m and is controlled to maintain a flow velocity of 0.5 to 5 m/s.

5. The method of claim 1, wherein the refrigerant introduced into the refrigerant evaporator has a pressure ranging from 0.5 to 40 bar and a temperature ranging from 10 to 60°C.

6. The method of claim 1, wherein the refrigerant compressor uses electrical energy to increase the pressure of the refrigerant stream introduced into the refrigerant compressor by 1.2 to 5 times.

7. The method of claim 1, wherein the compressed refrigerant stream has a temperature ranging from 90 to 200°C.

8. The method of claim 1, wherein the refrigerant stream condensed by the heat exchange with water in the refrigerant condenser has a temperature ranging from 85 to 170°C.

9. The method of claim 1, wherein the hot water obtained by heat exchange between the refrigerant stream and water in the refrigerant condenser has a temperature ranging from 85 to 180°C.

10. The method of claim 1, wherein the hot water is obtained by adjusting the water passing through the refrigerant condenser to be discharged at a pressure higher than its vapor pressure.

11. The method of claim 1, wherein the steam obtained by heat exchange between the refrigerant stream and water in the refrigerant condenser has a pressure ranging from 0.5 to 16 bar.

12. The method of claim 1, wherein the steam is obtained by adjusting the water passing through the refrigerant condenser to be discharged at a pressure lower than its vapor pressure.

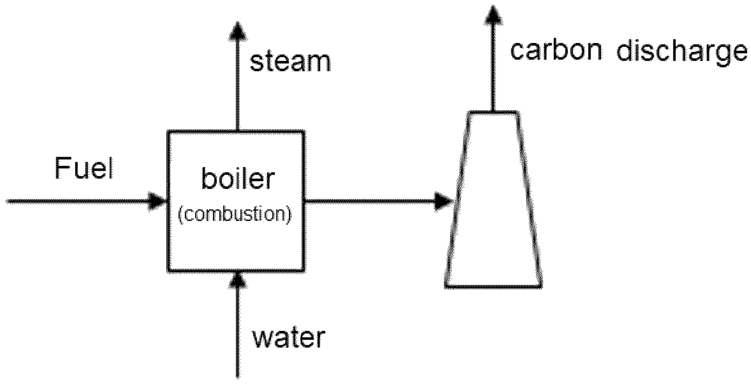
13. The method of claim 1, wherein the steam flowing out of the refrigerant condenser is additionally compressed, converted into high-pressure steam, and then used as a process heat source.

14. A system for preparing steam or hot water, comprising:

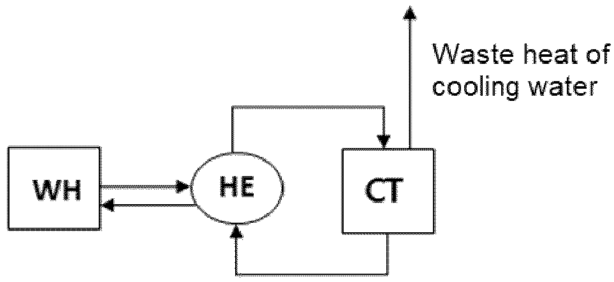
a plurality of waste heat sources, heat exchangers configured in a number corresponding to the plurality of waste heat sources, and a heat pump device connected to the heat exchangers through an integrated pipe and a branch pipe,
wherein the heat pump device includes a refrigerant evaporator, a refrigerant compressor, a refrigerant condenser, and a refrigerant expansion valve connected through a pipe, and
the heated cooling water flowing out of each of the heat exchangers is combined through the integrated pipe and introduced into the refrigerant evaporator of the heat pump device, following by heat exchange with a refrigerant to vaporize the refrigerant, and then passed through the branch pipe, followed by circulating to each of the heat exchangers.

15. The system of claim 14, wherein the refrigerant condenser of the heat pump device is connected to an additional steam compressor.

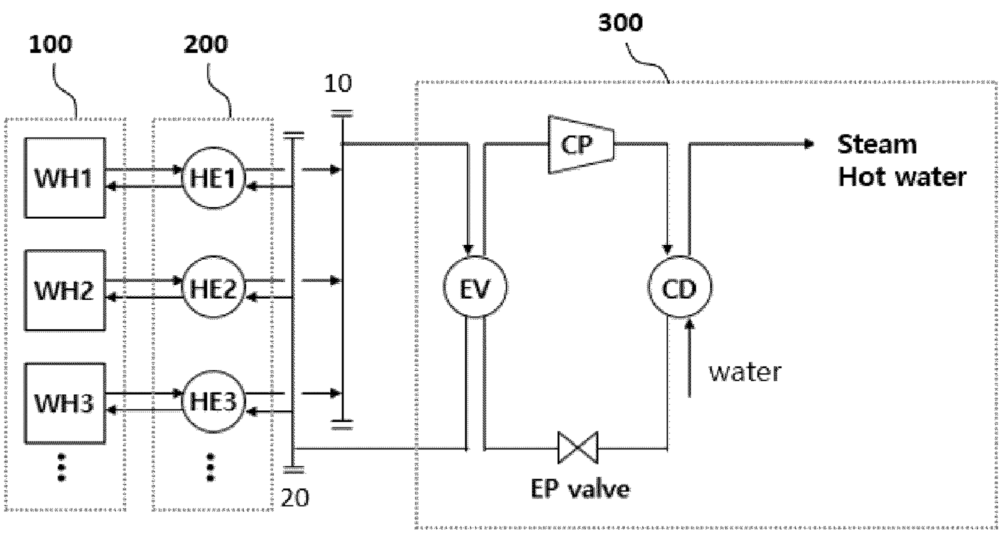
[FIG. 1]



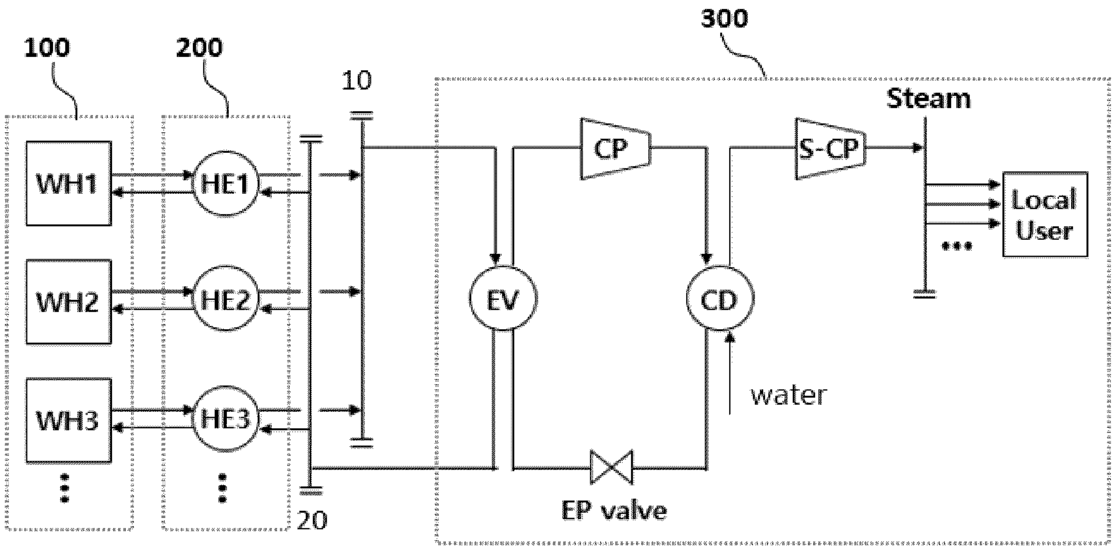
[FIG. 2]



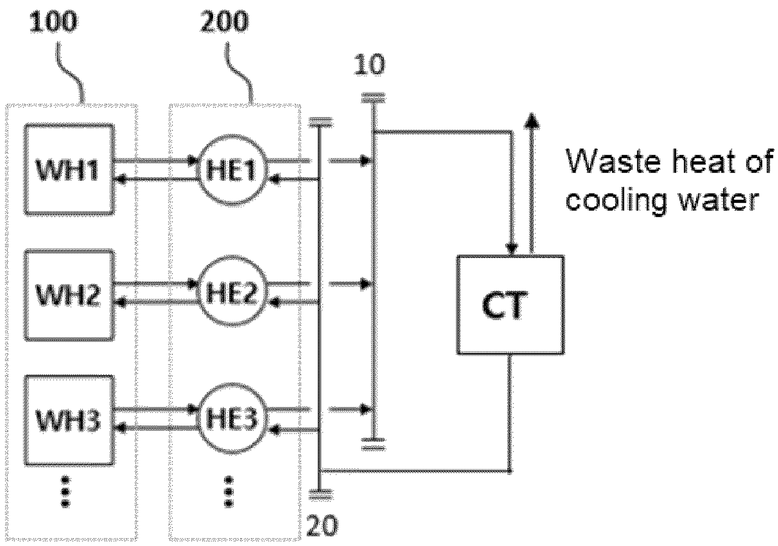
[FIG. 3]



[FIG. 4]


300
100
200
10
Steam
WH1
HE1
CP
S-CP
Local
User
WH2
HE2
EV
CD
WH3
HE3
water
20
EP valve

[FIG. 5]


100
200
10
WH1
HE1
Waste heat of
cooling water
WH2
HE2
CT
WH3
HE3
20

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2024/095367

A. CLASSIFICATION OF SUBJECT MATTER

F22B 1/18(2006.01)i; **F22B 31/04**(2006.01)i; **F24D 17/00**(2006.01)i; **F25B 27/02**(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F22B 1/18(2006.01); F01K 13/02(2006.01); F22B 1/16(2006.01); F22B 3/00(2006.01); F23J 15/06(2006.01); F25B 27/02(2006.01); F25B 30/02(2006.01); F28D 20/02(2006.01)

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

Korean utility models and applications for utility models: IPC as above
Japanese utility models and applications for utility models: IPC as above

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

eKOMPASS (KIPO internal) & keywords: 폐열(waste heat), 열교환기(heat exchanger), 복수(plurality), 냉각수(cooling water), 증발기(evaporator), 스팀(steam), 온수(hot water), 통합 배관(combined pipe)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2016-161248 A (FUJI ELECTRIC CO., LTD.) 05 September 2016 (2016-09-05) See paragraphs [0026]-[0031] and [0041] and figure 1.	1-15
Y	KR 10-2020-0122361 A (ORCAN ENERGY AG) 27 October 2020 (2020-10-27) See paragraphs [0032]-[0033] and [0050]-[0051] and figures 1 and 4.	1-15
A	CN 105444196 A (DINGLI SHICHUANG INTELLIGENT CONTROL TECHNOLOGY (BEIJING) CO., LTD.) 30 March 2016 (2016-03-30) See paragraphs [0034]-[0037] and figure 1.	1-15
A	JP 2004-198022 A (ISHIKAWAJIMA HARIMA HEAVY IND. CO., LTD.) 15 July 2004 (2004-07-15) See paragraphs [0015]-[0022] and figure 1.	1-15
A	KR 10-1340640 B1 (AIRTEC CO., LTD.) 20 December 2013 (2013-12-20) See paragraphs [0046]-[0054] and figures 1-5.	1-15

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "D" document cited by the applicant in the international application
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 May 2024	**28 May 2024**

Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office **Government Complex-Daejeon Building 4, 189 Cheongsa-ro, Seo-gu, Daejeon 35208**	
Facsimile No. **+82-42-481-8578**	Telephone No.

Form PCT/ISA/210 (second sheet) (July 2022)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2024/095367

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2016-161248 A	05 September 2016	JP 6528467 B2	12 June 2019
KR 10-2020-0122361 A	27 October 2020	BR 112020016793 A2	15 December 2020
		CN 111902613 A	06 November 2020
		DK 3530890 T3	16 January 2023
		EP 3530890 A1	28 August 2019
		EP 3530890 B1	12 October 2022
		JP 2021-515138 A	17 June 2021
		JP 7229276 B2	27 February 2023
		KR 10-2615752 B1	19 December 2023
		US 11352911 B2	07 June 2022
		US 2021-0003039 A1	07 January 2021
		WO 2019-166137 A1	06 September 2019
CN 105444196 A	30 March 2016	CN 105444196 B	31 October 2017
JP 2004-198022 A	15 July 2004	None	
KR 10-1340640 B1	20 December 2013	KR 10-2013-0029545 A	25 March 2013

Form PCT/ISA/210 (patent family annex) (July 2022)

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

- KR 1020230050549 **[0001]**
- KR 1020240021815 **[0001]**