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

(11) EP 3 653 952 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
20.05.2020 Bulletin 2020/21

(51) Int Cl.:
F25B 39/02 *(2006.01)* ***F25B 25/00*** *(2006.01)*

(21) Application number: **18206574.8**

(22) Date of filing: **15.11.2018**

(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 MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(71) Applicant: **Standard Fasel B.V.**
3543 AP Utrecht (NL)

(72) Inventor: **SCHEEPENS, Adrianus Antonius Hubertus**
5019 DH OOSTELBEERS (NL)

(74) Representative: **Jilderda, Anne Ayolt**
LIOC Patents & Trademarks
Zwaanstraat 31 L
5651 CA Eindhoven (NL)

(54) HEAT DELIVERY DEVICE

(57) A heat delivery device receives a first heat-carrying medium (1) at a feed temperature and delivers a second heat-carrying medium (2) at a delivery temperature which is higher than the feed temperature of the first medium. The device comprises a reservoir (10) for the second medium in liquid form and in heat-exchanging contact with the first medium. Compression means (20) are provided so as to receive the second medium in vapour form from the reservoir, compress the medium adiabatically and provide it to the outlet at an increased pressure and the delivery temperature.

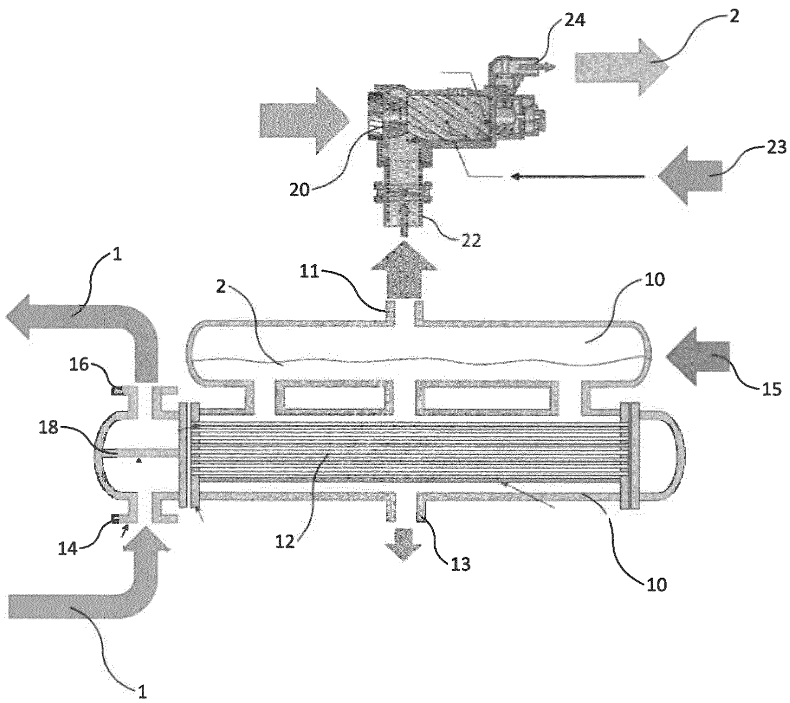

Fig.1

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Description

[0001] The present invention relates to a heat delivery device comprising an inlet for receiving a first heat-carrying medium at a feed temperature, an outlet for delivering a second heat-carrying medium at a delivery temperature which is higher than the feed temperature of the first medium, comprising a reservoir in which during operation the second medium is received in liquid form, and comprising heat transfer means which enable the second medium to enter into heat-exchanging contact with the first medium.

[0002] With a view to achieving global climate objectives many governments are committed to an energy transition for switching from burning fossil fuels to more sustainable forms of energy delivery. An essential part of this is efficient use of residual heat. This is for instance industrial residual heat and energy released at domestic waste and other incineration plants. These residual heat flows can be utilized to supply a heat network typically having a feed temperature in the order of 60 to 80 degrees Celsius. In addition to residual heat from industrial and other processes, geothermal heat can also be coupled into the same or similar network. This heat can subsequently be employed as main or additional heating source for buildings in the heating season.

[0003] In geographical regions where there is no heating season, this does not however provide a solution for efficient reuse of residual heat flows. Outside the heating season and during mild winters there will also be a significant surplus of residual heat which cannot be utilized or not fully utilized. The present invention has for its object, among others, to provide a solution herefor.

[0004] The invention is based here on the insight that within small and medium-sized industry a great deal of process heat is not needed seasonally, or at least needed to lesser extent, but that a temperature is required here of (well) above 100 degrees Celsius, which hereby lies considerably higher than is usual in residual heat flows. The invention therefore has for its object, among others, to provide a heat delivery device with which an energy carrier at an increased feed temperature can be realized for suchlike and other processes from residual heat and other flows of a lower temperature.

[0005] In order to achieve the stated object a heat delivery device of the type described in the preamble has the feature according to the invention that the device comprises compression means which are able and configured to receive the second medium in vapour form from the reservoir and to provide the medium to the outlet at an increased pressure and the delivery temperature.

[0006] Using the device primary energy is thus extracted from the first medium, for which purpose a residual heat flow or geothermic source can advantageously be applied at a temperature typically in the order of magnitude of 60 to 100 degrees Celsius. This heat is utilized to evaporate the second medium. The vapour form therefrom is compressed with the compression means provided for the purpose. The thereby resulting pressure increase is accompanied, on the basis of the universal gas law, by a proportional increase in temperature of the second medium which will possibly become superheated.

[0007] This hotter or even superheated second medium can be drawn off at the outlet as energy carrier at a temperature if desired of (well) above 100 degrees Celsius, and is highly suitable for heating many industrial and other processes where such a relatively high process temperature is desired. A large part of this energy comes from the primary energy flow; only a limited part need be added to drive and control the device itself, in particular for operation of the compression means. The invention hereby provides a heat delivery device which can convert residual heat to useful heat at a higher temperature without the intervention of an external medium such as a coolant as applied in heat pumps.

In order to enhance evaporation of the second medium a boiling point of the liquid can be effected by means of a pressure decrease. A preferred embodiment of the device has for this purpose the feature according to invention that means are provided to maintain an underpressure in the reservoir during operation which results in a lowering of the boiling point of the second medium, and in particular that the underpressure is sufficient to lower a boiling point of the second medium to below the feed temperature of the first medium.

[0008] Said underpressure can be created by means of pump means provided specifically for the purpose. A further preferred embodiment of the device according to the invention has the feature however that the compression means are able and configured to extract the second medium in vapour form from the reservoir during operation and to impose the underpressure on the reservoir while doing so. The compression means are thus also utilized as pump means in order to maintain said underpressure in the reservoir. The device as a whole can hereby be kept relatively simple and compact.

[0009] Although the second medium can already have been in heat-exchanging contact with the first medium prior to introduction in order to extract heat therefrom, a particular preferred embodiment of the device has the feature according to the invention that the heat transfer means are provided in or close to the reservoir in order to allow the second medium to enter into heat-exchanging contact therein with the first medium. The second medium can be supplied directly here to the reservoir from a source, after which the intended heat transfer from the first medium to the second medium takes place in the reservoir in order to heat the second medium.

[0010] A further preferred embodiment of the device according to the invention has the feature here that the reservoir is provided with at least one heat exchanger, via which the second medium enters into heat-exchanging contact with the first medium, which heat exchanger comprises the inlet and is provided with an outlet at which the first medium can be drawn off at a decreased temperature. The heat exchanger, which is received here in or close to the reservoir, provides for a heat transfer from the first medium to the second medium. The heat exchanger here provides a separate closed circuit for the first medium which, after having been guided through the heat exchanger, has relinquished energy (heat) without being contaminated with another medium. A quantity of heat generated by the heat exchanger can be regulated here on the basis of for instance a pressure in the reservoir and/or a temperature of the first medium exiting therefrom. The heat exchanger need not be accommodated physically in the reservoir here. It will suffice that a thermodynamic heat exchange is possible between the heat exchanger and the second medium present in the reservoir. This is also possible with a heat exchanger placed outside the reservoir.

[0011] With a view to a pressure and temperature difference (underpressure) to be created therein relative to the surrounding area, the reservoir is preferably closed gas-tightly and thermally insulated. A further preferred embodiment of the device according to the invention is characterized for this purpose in that the reservoir comprises a thermally insulated vacuum boiler with an optionally modulating level control which maintains an at least substantially fixed level of the second medium. In the vacuum boiler energy present in the first medium is utilized for a phase change of the second medium from liquid to vapour form. Depending on a feed temperature of the first medium from which the heat is extracted, an underpressure can be maintained therefor in the vacuum boiler in those cases where said feed temperature lies below a boiling point of the second medium at atmospheric pressure and a positive temperature difference has to be realized between this feed temperature and a temperature at which the second medium has to emerge at the outlet. The vacuum boiler is otherwise preferably provided with a pressure relief device, for instance an exhaust valve, in order to avoid dangerous situations in the case of calamities.

[0012] The second medium is preferably supplied to the boiler in the form of a (pre-)degassed liquid. A level thereof in the boiler is monitored and held at a desired level by means of the (modulating) level control. In order to also maintain a quality of the second medium in the vacuum boiler at a desired level it may be desirable to wholly or partially drain off the content thereof continuously or periodically. With this in mind a further preferred embodiment of the device has the feature according to invention that the vacuum boiler comprises a pump provision for drawing off discharge liquid. The pump provision provides a means here for drawing off discharge water from the boiler while an underpressure prevails therein.

[0013] In a particular embodiment the device is characterized according to the invention in that the compression means comprise one or more compressor stages, each with one or more compressors, in particular one or more centrifugal, piston, screw, lobe or hybrid compressors. A vapour formed from the second medium is thus increased in pressure by means of one or more compression steps so that this vapour flow will be usable in terms of pressure, temperature and energy content for a consumer coupled to the device. Various compressor technologies can be applied for this purpose, such as for instance but not limited to, centrifugal, piston, screw, lobe and hybrid compressors.

[0014] When the compression means comprise two or more compression stages, there will be an intermediate pressure therebetween. In order to absorb this intermediate pressure a further particular embodiment of the device has the feature according to the invention that the compression means comprise two or more successive compressor stages which are each controllable, in particular by being provided by a speed or capacity control, and that a pressure vessel is received between successive compressor stages, preferably in combination with an electronic pressure sensor coupled to the speed control of one or more compressors. The pressure sensor preferably applied here thus provides a feedback to the speed control or capacity control of the compressor(s) coupled thereto for the purpose of an at least substantially controlled pressure regulation. A variable pressure regulation such as a speed or capacity control moreover provides the option of adjusting the output, or power supply, of the device to a demand of a consumer coupled thereto. A delivered quantity of the compressed second medium is controllable within determined limits by increasing or decreasing a speed, capacity or other power parameter of the compression means.

[0015] Energy necessary for the intended pressure increase of the second medium is supplied by means of a mechanical driving of the compression means in electrical or other manner. A part of this energy is converted by adiabatic compression to internal energy of the second medium. A small part dissipates to the surrounding area as a result of friction and thermal losses. In order to limit a rise in the temperature of the second medium and/or prevent superheating in the compression means, a further embodiment of the device has the feature according to the invention that the at least one compressor is provided with a cooling on the basis of a cooling medium, and preferably that for the cooling medium the second medium is applied which for this purpose is drawn off from the reservoir and guided back to the reservoir. The second or other medium is brought here into thermal contact in liquid form with the compression means, whereby heat is absorbed and the cooling medium will evaporate and in this way extract superheating energy from the compression means.

[0016] When the same medium as the second medium is applied for cooling of the compression means, it is preferably made liquid again, for instance by interposing an internal heat exchanger in or close to the reservoir of the second medium. The advantage hereof is that there are no dissolved salts present in the returned liquid which could otherwise result in damage to the installation, and in particular to the compression means. In a further preferred embodiment the device is characterized here according to the invention is in that the cooling medium also serves as seal for the second medium in the compressor. The second medium is applied here both as cooling and to seal the eventual vapour as energy carrier so that no (false) air is drawn in from outside.

[0017] The underlying principle of the invention is suitable in principle for any appropriate second medium which has a phase change from liquid to the vapour phase within the described temperature range. A particularly practical medium in this respect is water, which has a transition to water vapour, i.e. steam. A further preferred embodiment of the device according to the invention therefore has the feature that the second medium comprises water and the compression means are able and configured to deliver superheated steam from water vapour exiting therefrom.

[0018] The invention will be further elucidated hereinbelow with reference to an exemplary embodiment and an accompanying drawing. In the drawing:

Figure 1 shows a schematic representation of an exemplary embodiment of the device according to the invention; and

Figure 2 shows a possible process diagram for the device of figure 1.

It is otherwise noted here that the figures are purely schematic and not always drawn to (the same) scale. Some dimensions in particular may be exaggerated to greater or lesser extent for the sake of clarity. Corresponding parts are designated in the figures with the same reference numeral.

[0019] The device shown in figure 1 comprises a (vacuum) boiler 10 in which or wherein a heat exchanger 12 is received. Heat exchanger 12 is supplied with a first medium 1, for instance a warm water flow obtained from a residual heat network or coming directly from an industrial or other installation, such as for instance a combined heat and power plant or a heat pump. A feed temperature of such a warm water flow is typically in the order of 60 to 100°C. This primary medium is provided at a primary inlet 14 of the device and drawn off at a primary outlet 16 after being guided through a pipe system or plate system of heat exchanger 12. Situated between the inlet and outlet is a liquid barrier 18 which prevents the primary medium flowing directly from inlet 14 to outlet 16. It will otherwise be apparent that, at a feed temperature of the first medium which is already above the atmospheric boiling point of the second medium, an underpressure can be dispensed with in boiler 10 and an atmospheric or even a small overpressure can prevail in the boiler. The type of heat exchanger 12 can also be of diverse nature within the context of the invention. What is important is that the heat exchanger is able and configured to bring about a heat transfer from the first medium to the second medium wherein the second medium is situated in reservoir 10 and is driven to a phase change from liquid to gas (vapour or steam).

[0020] The residual heat supply (quantity of water) is controlled with a control circuit PC-1 provided for the purpose, see figure 2, on the basis of an actual pressure in the vacuum boiler. The use of residual heat hereby depends indirectly on the steam production. The set point SP is a variable depending on the feed temperature of the residual heat. The set point SP is entered as difference in temperature above the corresponding saturation temperature of the measured pressure.

[0021] Boiler 10 is filled to a desired level with a second medium 2, for which in this example water is likewise applied. The level of the vacuum boiler is kept constant using a modulating feed water control LC-1, see figure 2, coupled to an inlet 13 of the boiler. The level in the boiler is hereby held at a fixed value, for instance at 50% of a maximum level, and replenished as soon as necessary from a water supply BFW. The boiler is supplied with hot water at around boiling point so as to not disrupt the thermodynamics of the device. In order to prevent undesired damage by corrosion, dissolved gases are preferably removed as far as possible therefrom by means of a suitable degassing.

[0022] A quality of the water in vacuum boiler 10 is continuously monitored and controlled so that no damage or decline in performance occurs as a result of a degree of too high a contamination of the water. An automatic drain 17 at the bottom provides for the discharge of concentrated contaminated water. Because a vacuum can optionally prevail in boiler 10, a special drain pump 19 is applied for this purpose. The automatic drain 17 is controlled with a control circuit QC-1 and has a fixed setting here of for instance 3000 μS/cm. When this value is exceeded, discharge water will be drained off to an outlet BD.

[0023] Heat exchanger 12 provides for a thermodynamic heat transfer from primary medium 1 to second medium 2 which is located in boiler 10 and which will thereby increase in temperature. Partly as a result of the underpressure prevailing in boiler 10 the water will evaporate therein to water vapour/steam which is drawn in by a compressor 20. An inlet 22 of compressor 20 is connected directly or indirectly for this purpose to an outlet 11 of boiler 10 and thus optionally provides automatically for an underpressure in the boiler. A water/steam separation in the boiler avoids water exiting via the same outlet 11.

[0024] Compressor 20 brings about an adiabatic compression of the removed steam. The pressure increase to an order of magnitude of 4-10 bar caused hereby results, on the basis of the universal gas laws of Gay-Lussac, in a strong increase in temperature of second medium 2. The eventual steam temperature can typically rise in the given example to an order of magnitude of 140-160°C at a pressure of 5 bar, and thereby lies significantly above the atmospheric boiling point of water. The device thus delivers superheated steam as energy carrier for a consumer which is coupled to the device and which derives advantage from such a higher feed temperature compared to the feed temperature of the primary residual heat flow. The energy required for this increase in temperature is delivered by the energy of compressor 20, which is driven mechanically in electrical or other manner for this purpose. A greater part of the energy content of the second medium provided at a secondary outlet 24 of the device does however come from the first medium which has been transferred for this purpose via the heat exchanger.

[0025] By means of one or more compression stages 20, 20', see also figure 2, vacuum steam/water vapour is thus increased in pressure and temperature to a level which is optimally usable for the specific consumer which has to be supplied by the device. Compressors 20, 20' each have a speed control or capacity control M with which the power, and thereby the amount of steam which is delivered, can be increased or limited as desired. Applied behind, i.e. downstream of, the compressors is a pressure vessel 21, 21' with a pressure sensor 23, see also figure 2, with which the compressors can be set via a suitable feedback circuit PC-2, PC-3 so that a speed/capacity and power of the compression means are adjusted to an energy content (amount), temperature and pressure of superheated steam to be delivered.

[0026] The capacity of first compressor 20 is controlled on the basis of a desired final pressure at outlet 24. When takeoff of second medium 2 increases, the pressure drops at the outlet and a maximum compressor capacity will be reached, wherein for instance compressor(s) 20 speed up until a maximum speed is reached. The set point SP is a fixed value, typically 4 barg. The capacity of second compressor 20' is controlled on the basis of an intermediate pressure which is measured with the associated pressure sensor. When the takeoff of the second medium at outlet 24 increases, this pressure also drops and an increased capacity will be required from both compressors until a maximum is reached here too, wherein for instance compressor(s) 20, 20' speed up to a maximum speed. The set point SP is a fixed value, here typically 0.05 barg.

[0027] On the basis of a primary (residual) heat flow at 60-80 degrees Celsius the shown installation is typically able, by means of the heat exchanger and the vacuum boiler, to deliver superheated steam at a temperature in the order of 140-180°C and a pressure in the order of 4-10 bar depending on the number of compression stages employed.

[0028] In order to prevent overheating of the compressors 20 themselves, they are cooled with water from the boiler. By guiding this water between the moving parts, such as a turbine, and an outer casing of the compressor heat is extracted from the mechanical parts of the compressor and an airtight seal is moreover provided for the internal parts of the compressor in order to avoid false air being drawn in. The maximum superheating of the first compressor is controlled with a first control circuit TC-1. Injecting water during the compression results in lower temperatures whereby a higher compression efficiency is realized. The set point SP is entered as temperature difference, for instance 5°C, above the corresponding saturation temperature of the measured pressure. In the same way the maximum superheating of second compressor 20' is likewise controlled with a second control circuit TC-2. By here also injecting water during the compression, which brings about lower temperatures, a higher compression efficiency is also realized here. The set point SP of this circuit TC-2 is entered as temperature difference, for instance 20°C, above the corresponding saturation temperature of the measured pressure.

[0029] During start-up and hot-standby HS the steam/vapour-sided whole of the device is brought under light overpressure by means of external steam. The whole is hereby brought to and held at temperature and non-condensable gases can be discharged. A provision for this latter is arranged at one or more positions.

[0030] Although the invention has been further elucidated above with reference to only a single exemplary embodiment, it will be apparent that the invention is by no means limited thereto. On the contrary, many variations and embodiments are still possible within the scope of the invention for a person with ordinary skill in the art. The device according to the invention is thus not only suitable for a heat supply for diverse industrial and other processes from a residual heat network, the device can for instance also be coupled to a heat pump of various dimensions in order to bring a feed temperature to a higher level. On relatively smaller scale a heat source for heating dwellings and buildings can thus be realized at a sufficiently high set point temperature in order to also make residual heat and geothermic energy possible in energetic situations which are less than optimal. The invention hereby makes an important contribution toward achieving the currently advocated energy transition.

Claims

1. Heat delivery device comprising an inlet for receiving a first heat-carrying medium at a feed temperature, an outlet for delivering a second heat-carrying medium at a delivery temperature which is higher than the feed temperature of the first medium, comprising a reservoir in which during operation the second medium is received in liquid form, and comprising heat transfer means which enable the second medium to enter into heat-exchanging contact with the first medium, **characterized in that** the device comprises compression means which are able and configured to receive the second medium in vapour form from the reservoir and to provide the medium to the outlet at an increased pressure and the delivery temperature.

2. Device as claimed in claim 1, **characterized in that**

means are provided to maintain an underpressure in the reservoir during operation, resulting in a lowering of the boiling point of the second medium.

3. Device as claimed in claim 2, **characterized in that** the underpressure is sufficient to lower a boiling point of the second medium at least substantially to below the feed temperature.

4. Device as claimed in claim 2 or 3, **characterized in that** the compression means are able and configured to extract the second medium in vapour form from the reservoir during operation and to impose the underpressure on the reservoir while doing so.

5. Device as claimed in one or more of the foregoing claims, **characterized in that** the heat transfer means are provided in or close to the reservoir in order to allow the second medium to enter into heat-exchanging contact therein with the first medium.

6. Device as claimed in claim 5, **characterized in that** the reservoir is provided with at least one heat exchanger, via which the second medium enters into heat-exchanging contact with the first medium, which heat exchanger comprises the inlet and is provided with an outlet at which the first medium can be drawn off at a decreased temperature.

7. Device as claimed in one or more of the foregoing claims, **characterized in that** the reservoir comprises a thermally insulated vacuum boiler with an optionally modulating level control which maintains an at least substantially fixed level of the second medium.

8. Device as claimed in claim 7, **characterized in that** the vacuum boiler comprises a pump provision for drawing off discharge liquid.

9. Device as claimed in one or more of the foregoing claims, **characterized in that** the compression means comprise one or more compressor stages, each with one or more compressors, in particular one or more centrifugal, piston, screw, lobe or hybrid compressors.

10. Device as claimed in claim 9, **characterized in that** the compression means comprise two or more successive compressor stages which are provided with a control such as a speed control or otherwise a capacity control, and that a pressure vessel is received between successive compressor stages, preferably in combination with an electronic pressure sensor coupled to the speed control of one or more compressors.

11. Device as claimed in claim 9 or 10, **characterized in that** the at least one compressor is provided with a cooling on the basis of a cooling medium.

12. Device as claimed in claim 11, **characterized in that** for the cooling medium the second medium is applied which for this purpose is drawn off from the reservoir and guided back to the reservoir.

13. Device as claimed in claim 12, **characterized in that** the cooling medium also serves as seal for the second medium in the compressor.

14. Device as claimed in one or more of the foregoing claims, **characterized in that** the second medium comprises water and the compression means are able and configured to deliver superheated steam from water vapour exiting therefrom.

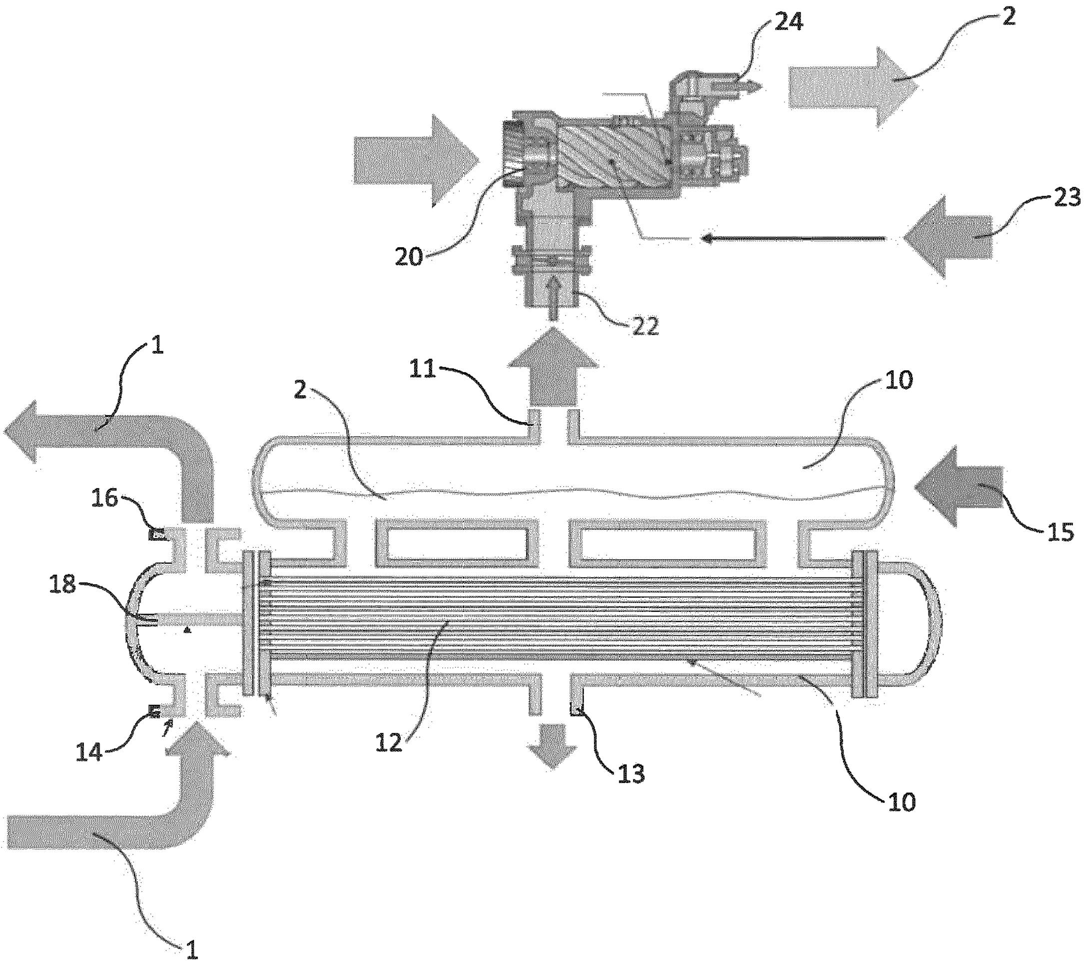
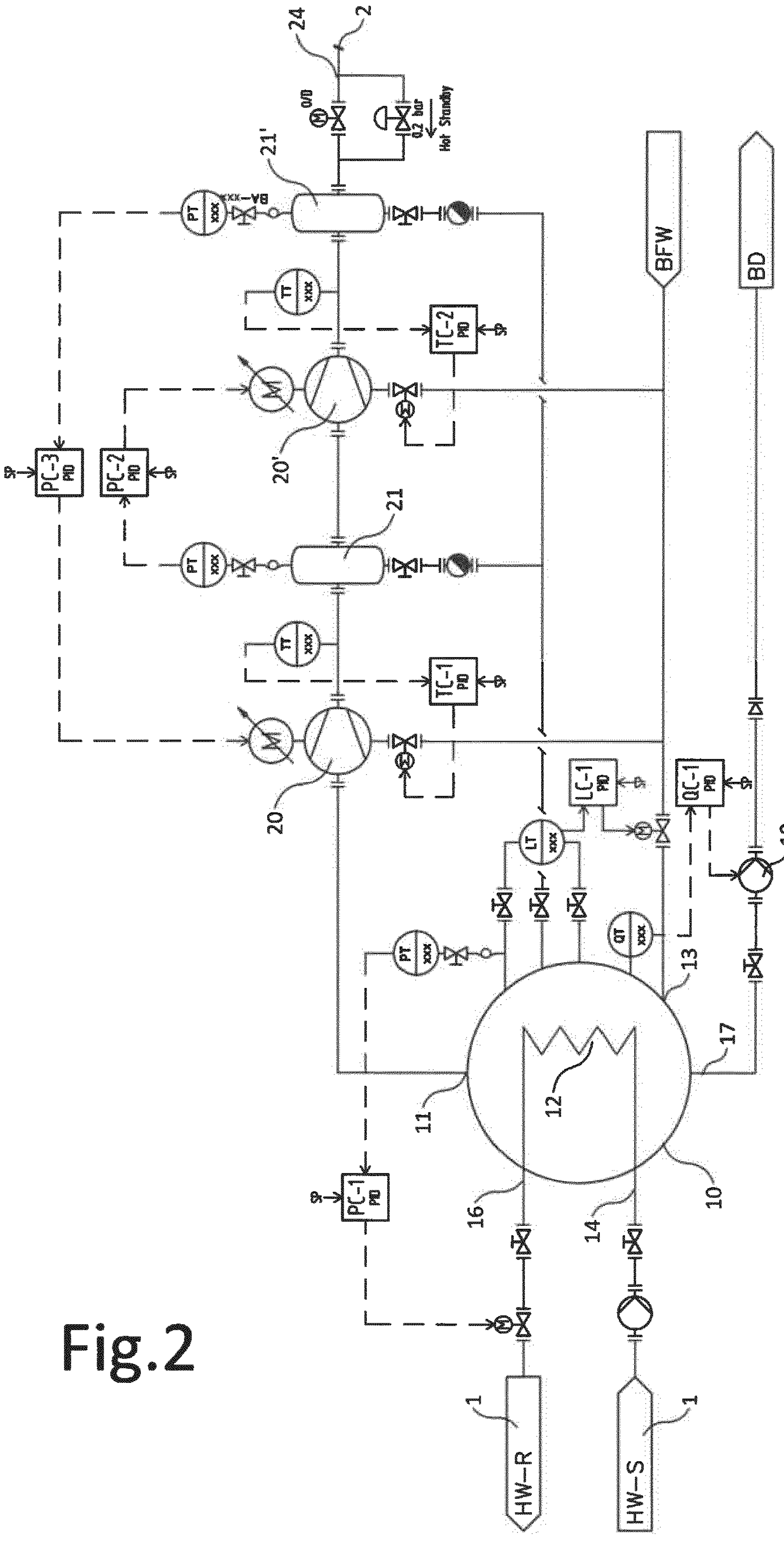


Fig.1



HW-R
HW-S
BFW
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PC-2
PC-3
TC-1
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LC-1
QC-1
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0,2 bar
Hot Standby
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Fig.2

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EUROPEAN SEARCH REPORT

Application Number
EP 18 20 6574

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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TECHNICAL FIELDS SEARCHED (IPC)

F25B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	15 April 2019	Gasper, Ralf

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 18 20 6574

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