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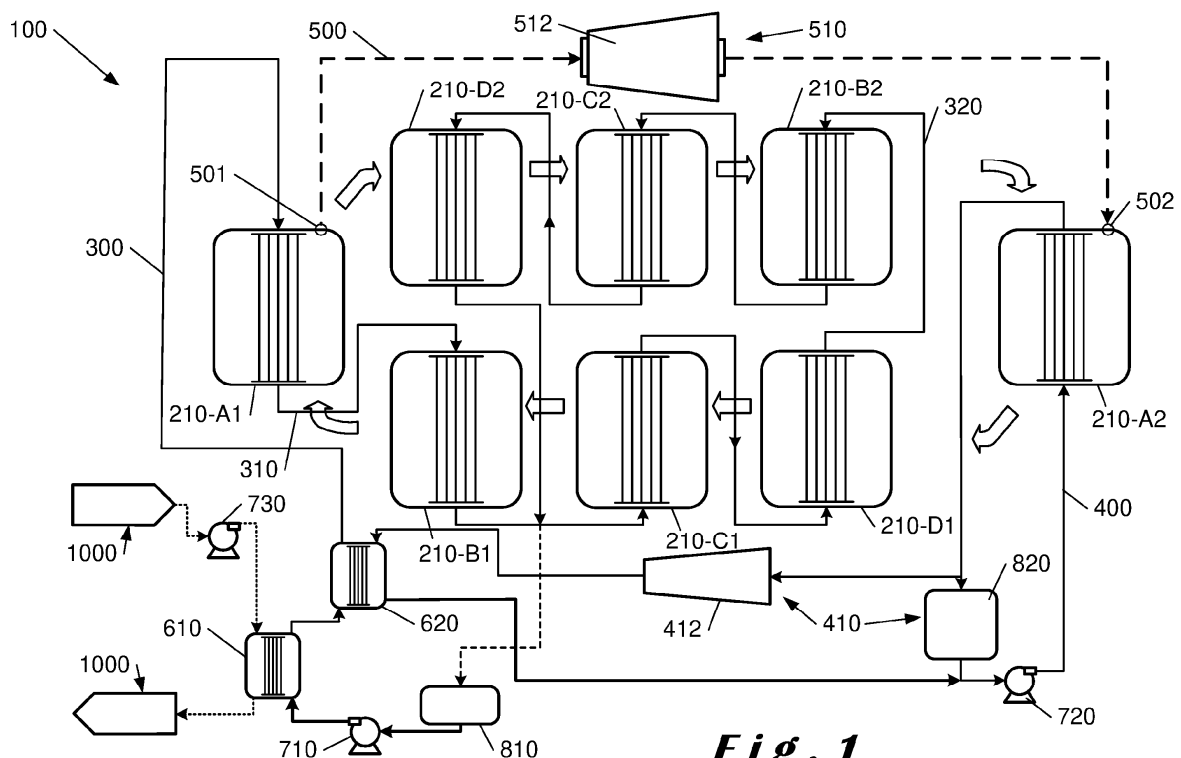
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(54) SYSTEM AND METHOD FOR GENERATING POWER FROM A HEAT SOURCE

(57) The invention provides a system (100) for generating power from a heat source (1000). The system (100) comprises a charged and discharged adsorption vessel (210) with an adsorbent bed (220). An adsorbate is adsorbed on the adsorbent bed (220) of the charged adsorption vessel (210). A heating circuit (300) is coupled to the charged adsorption vessel (210), and a first heat exchange medium heated by the heat source (1000) is circulated therethrough for heating the charged adsorption vessel (210) and as such desorbing the adsorbate. A

cooling circuit (400) is coupled to the discharged adsorption vessel (210), and a second heat exchange medium actively cooled by a cooling device (410) is circulated therethrough for cooling the discharged adsorption vessel (210) and as such adsorbing received adsorbate. A power generation circuit (500) with a power generation device (510) couples the charged and discharged adsorption vessel (210) for passing the adsorbate therebetween. Power is generated with the power generation device (210) by means of the passing adsorbate.

**Fig. 1****EP 4 818 483 A1**

Description**Technical field**

5 **[0001]** The present invention relates to a system for generating power from a heat source. Furthermore, the present invention also relates to a method for operating the system according to the present invention, i.e. a method for generating power from a heat source by means of the system according to the present invention.

Background art

10 **[0002]** From the prior art systems are known which make use of temperature swing adsorption compression, TSAC, for generating power from a heat source. Such systems comprise a first adsorption vessel and a second adsorption vessel, each comprising an adsorbent bed. The system comprises an adsorbate suitable for being adsorbed on and desorbed from the adsorbent bed of each adsorption vessel. In use, the adsorbate is adsorbed substantially, i.e. mainly, on the
 15 adsorbent bed of one of the adsorption vessels, which adsorption vessel is referred to as a charged adsorption vessel, and the other one as a discharged adsorption vessel. The system comprises a heating circuit. The heating circuit is configured for being selectively coupled to the charged adsorption vessel. The heating circuit is configured for circulating a first heat exchange medium through a coupled adsorption vessel. The heating circuit is configured for being coupled to the heat source for heating the first heat exchange medium entering the coupled adsorption vessel in order to heat the coupled
 20 adsorption vessel for desorbing the adsorbate from the adsorbent bed of the coupled adsorption vessel. The system comprises a power generation circuit configured for being selectively coupled at a first end to the charged adsorption vessel coupled to the heating circuit and at a second end to the discharged adsorption vessel. The power generation circuit is configured for passing the adsorbate from the charged adsorption vessel coupled to the heating circuit to the discharged adsorption vessel on which adsorbent bed the adsorbate can be adsorbed. The power generation circuit comprises a
 25 power generation device, such that power is generated when the adsorbate passes from the charged adsorption vessel coupled to the heating circuit to the discharged adsorption vessel.

[0003] In a first phase of a power generation cycle of such a system the adsorbate is adsorbed substantially on the adsorbent bed of the first adsorption vessel, which forms in this phase the charged adsorption vessel. In this phase only a small residual amount of adsorbate is adsorbed on the adsorbent bed of the second adsorption vessel, which forms in this
 30 phase the discharged adsorption vessel. The heat source is coupled to the heating circuit. The first adsorption vessel is coupled to the heating circuit and to the first end of the power generation circuit. The second adsorption vessel is coupled to the second end of the power generation circuit. The first adsorption vessel is then heated by circulating the first heat exchange medium in the heating circuit, which is heated by the heat source, through the first adsorption vessel for the purpose of desorbing the adsorbate from the adsorbent bed of the first adsorption vessel. The desorbed adsorbate in the
 35 first adsorption vessel greatly increases the pressure in the first adsorption vessel, as a consequence of which the desorbed adsorbate passes through the power generation circuit from the first adsorption vessel to the second adsorption vessel. Thereby, the desorbed adsorbate passes through the power generation device which generates power. The desorbed adsorbate is then received in the second adsorption vessel, which should be at a temperature below the temperature of the heat source. For this purpose the second adsorption vessel may be passively cooled. In the second
 40 adsorption vessel the received adsorbate is adsorbed on the adsorbent bed of the second adsorption vessel, which becomes the charged adsorption vessel, and the first adsorption vessel becomes the discharged adsorption vessel. In a second phase of the power generation cycle the first adsorption vessel is decoupled from the heating circuit and the second adsorption vessel is coupled to the heating circuit instead. The first adsorption vessel and the second adsorption vessel are also decoupled from respectively the first end and the second end of the power generation circuit, and the first
 45 adsorption vessel and the second adsorption vessel are respectively coupled to the second end and the first end of the power generation circuit. The second adsorption vessel is then heated by circulating the first heat exchange medium in the heating circuit, which is heated by the heat source, through the second adsorption vessel for the purpose of desorbing the adsorbate from the adsorbent bed of the second adsorption vessel. The desorbed adsorbate then passes through the power generation circuit from the second adsorption vessel to the first adsorption vessel via the power generation device,
 50 thereby generating power. The desorbed adsorbate is then received in the first adsorption vessel, which should be at a temperature below the temperature of the heat source. Therefore, the first adsorption vessel must thus first be left to cool down to said temperature after having been heated during the first phase of the power generation cycle. For this purpose the first adsorption vessel may be passively cooled. Under these conditions the received adsorbate is adsorbed on the adsorbent bed of the first adsorption vessel, which again becomes the charged adsorption vessel, and the second
 55 adsorption vessel again becomes the discharged adsorption vessel. After this the power generation cycle returns back to the first phase and the whole process is repeated.

[0004] The system known from the prior art however has the disadvantage that according to Carnot's theorem the maximum heat-to-power efficiency of the power generation by the system is determined by the difference in the

temperature of the charged adsorption vessel coupled to the heating circuit, which is heated by the heat of the heat source, and the temperature of the discharged adsorption vessel. As such, the efficiency of the power generation by the system is limited, certainly in case of a low temperature heat source with a temperature of at most 100°C.

5 Disclosure of the invention

[0005] It is an aim of the present invention to provide a system for generating power from a heat source with improved efficiency.

[0006] This aim is achieved according to the present invention with a system for generating power from a heat source showing the technical characteristics of the first independent claim, and with a method for operating the system according to the present invention showing the technical characteristics of the second independent claim.

[0007] Therefore, the present invention provides a system for generating power from a heat source. The system comprises at least one set of a first adsorption vessel and a second adsorption vessel. Each adsorption vessel, i.e. each adsorption vessel of the system, comprises an adsorbent bed. The adsorbent bed is a structure of an adsorbent material suitable for adsorbing and desorbing an adsorbate. Preferably, the adsorbent bed has a large external surface for adsorbing and desorbing an adsorbate. Preferably, each adsorption vessel comprises an internal heat exchanger through which a heat exchange medium can be passed for heating or cooling the adsorption vessel. The system comprises an adsorbate suitable for being adsorbed on and desorbed from the adsorbent bed of each adsorption vessel. The adsorbate is adsorbed substantially, i.e. mainly, on the adsorbent bed of one adsorption vessel of each set. Said one adsorption vessel of each set is referred to as a charged adsorption vessel. The other adsorption vessel of each set is referred to as a discharged adsorption vessel. The system comprises a heating circuit. The heating circuit is configured for being selectively coupled, i.e. selectively connected, to the charged adsorption vessel of any one of the at least one set. Preferably, the charged adsorption vessel selectively coupled to the heating circuit is referred to as a coupled adsorption vessel, i.e. as a primary coupled adsorption vessel, of the heating circuit. The heating circuit is configured for circulating a first heat exchange medium through a coupled adsorption vessel. Preferably, the first heat exchange medium is thereby circulated in a predetermined first flow direction through the heating circuit. The heating circuit is configured for being coupled, i.e. connected, to the heat source for heating the first heat exchange medium entering the coupled adsorption vessel in order to heat the coupled adsorption vessel for desorbing the adsorbate from the adsorbent bed of the coupled adsorption vessel. Preferably, the heating circuit is configured for being coupled to the heat source for heat exchange. Preferably, the heating circuit is configured for being coupled to the heat source via a first heat exchanger. Preferably, the heating circuit is configured for being coupled to the heat source for heating the first heat exchange medium with heat from the heat source before entering the primary coupled adsorption vessel. The system comprises a cooling circuit. The cooling circuit is configured for being selectively coupled, i.e. selectively connected, to the discharged adsorption vessel of the same set as the charged adsorption vessel selectively coupled to the heating circuit. Preferably, the discharged adsorption vessel selectively coupled to the cooling circuit is referred to as a coupled adsorption vessel, i.e. as a primary coupled adsorption vessel, of the cooling circuit. The cooling circuit is configured for circulating a second heat exchange medium through a coupled adsorption vessel. Preferably, the second heat exchange medium is thereby circulated in a predetermined second flow direction through the cooling circuit. The cooling circuit is coupled to a cooling device of the system configured for actively cooling the second heat exchange medium entering the coupled adsorption vessel in order to cool the coupled adsorption vessel for adsorbing adsorbate received in the coupled adsorption vessel on the adsorbent bed of the coupled adsorption vessel. Preferably, the cooling device is configured for actively cooling the second heat exchange medium by extracting heat from the second heat exchange medium before entering the coupled adsorption vessel. Preferably, the adsorbate received in the coupled adsorption vessel of the cooling circuit is thereby received from the coupled adsorption vessel of the heating circuit after being desorbed from the adsorbent bed of the coupled adsorption vessel of the heating circuit. The system comprises a power generation circuit. The power generation circuit is configured for being selectively coupled, i.e. selectively connected, at a first end to the adsorption vessel coupled to the heating circuit and at a second end to the adsorption vessel coupled to the cooling circuit. The power generation circuit is configured for passing the adsorbate from the adsorption vessel coupled to the heating circuit to the adsorption vessel coupled to the cooling circuit. The power generation circuit comprises a power generation device, such that power is generated when the adsorbate passes from the adsorption vessel coupled to the heating circuit to the adsorption vessel coupled to the cooling circuit through the power generation device.

[0008] For generating power the system according to the present invention is used as follows. Take a set with a first adsorption vessel and a second adsorption vessel, wherein the adsorbate is adsorbed substantially on the adsorbent bed of the first adsorption vessel. The heat source is coupled to the heating circuit.

[0009] In a first phase of a power generation cycle of the set the first adsorption vessel, i.e. the charged adsorption vessel in this first phase, is coupled to the heating circuit and to the first end of the power generation circuit, and the second adsorption vessel, the discharged adsorption vessel in this first phase, is coupled to the cooling circuit and to the second end of the power generation circuit. The first adsorption vessel is then heated by circulating the first heat exchange medium

in the heating circuit, which is heated by the heat source, through the first adsorption vessel for the purpose of desorbing the adsorbate from the adsorbent bed of the first adsorption vessel. The desorbed adsorbate in the first adsorption vessel greatly increases the pressure in the first adsorption vessel, as a consequence of which the desorbed adsorbate passes through the power generation circuit from the first adsorption vessel to the second adsorption vessel. Thereby, the desorbed adsorbate passes through the power generation device which generates power. The desorbed adsorbate is then received in the second adsorption vessel, which is actively cooled by means of the cooling circuit to a predetermined temperature below the temperature of the heat source. In the cooled second adsorption vessel the received adsorbate is adsorbed on the adsorbent bed of the second adsorption vessel, which becomes the charged adsorption vessel, and the first adsorption vessel becomes the discharged adsorption vessel.

[0010] In a second phase of the power generation cycle of the set the first adsorption vessel, i.e. the discharged adsorption vessel in this second phase, is then coupled to the cooling circuit and to the second end of the power generation circuit after having been decoupled from the heating circuit and the first end of the power generation circuit. The second adsorption vessel, i.e. the charged adsorption vessel in this second phase, is coupled to the heating circuit and to the first end of the power generation circuit after having been decoupled from the cooling circuit and the second end of the power generation circuit. The second adsorption vessel is then heated by circulating the first heat exchange medium in the heating circuit, which is heated by the heat source, through the second adsorption vessel for the purpose of desorbing the adsorbate from the adsorbent bed of the second adsorption vessel. The desorbed adsorbate then passes through the power generation circuit from the second adsorption vessel to the first adsorption vessel via the power generation device, thereby generating power. The desorbed adsorbate is then received in the first adsorption vessel, which is actively cooled by means of the cooling circuit to the predetermined temperature below the temperature of the heat source. In the cooled first adsorption vessel the received adsorbate is adsorbed on the adsorbent bed of the first adsorption vessel, which again becomes the charged adsorption vessel, and the second adsorption vessel again becomes the discharged adsorption vessel. After this the power generation cycle returns back to the first phase and the whole process is repeated.

[0011] In the system according to the present invention the cooling circuit offers the advantage that the difference in temperature between the charged adsorption vessel coupled to the heating circuit, which is heated by the heat of the heat source, and the temperature of the discharged adsorption vessel coupled to the cooling circuit, which is actively cooled by means of the cooling device, can be increased. Since, according to the Carnot's theorem, the maximum heat-to-power efficiency of the power generation by the system is determined by this difference, the increase in the temperature difference between the charged adsorption vessel coupled to the heating circuit and the discharged adsorption vessel coupled to the cooling circuit also increases the maximum heat-to-power efficiency and thus the efficiency of the power generation by the system according to the present invention. The active cooling of the discharged adsorption vessel by means of the cooling circuit also offers the advantage that the desired temperature of the discharged adsorption vessel can be reached more quickly, which speeds up the power generation process and thus increases its efficiency.

[0012] In an embodiment of the system according to the present invention the cooling device is configured for actively cooling the second heat exchange medium to a predetermined temperature. Preferably, the predetermined temperature is determined by the temperature of the heat source. Preferably, the predetermined temperature is at least 50°C, preferably at least 52°C, more preferably at least 54°C, even more preferably at least 56°C, yet even more preferably at least 58°C and most preferably at least 60°C below the temperature of the heat source. Preferably, the predetermined temperature is at most 90°C, preferably at most 88°C, more preferably at most 86°C, even more preferably at most 84°C, yet even more preferably at most 82°C and most preferably at most 80°C below the temperature of the heat source. More preferably, the difference between the temperature of the heat source and ambient temperature is thereby at most 80°C, preferably at most 76°C, more preferably at most 72°C, even more preferably at most 68°C, yet even more preferably at most 64°C and most preferably at most 60°C.

[0013] In an embodiment of the system according to the present invention the cooling device is also coupled, i.e. connected, to the heating circuit for heating with heat extracted from the second heat exchange medium the first heat exchange medium entering the adsorption vessel coupled to the heating circuit. Preferably, the cooling device is thereby coupled to the heating circuit for heat exchange. Preferably, the cooling device is thereby coupled to the heating circuit via a second heat exchanger. Preferably, the cooling device is thereby coupled to the heating circuit for heating the first heat exchange medium before entering the adsorption vessel coupled to the heating circuit.

[0014] This embodiment offers the advantage that the heat extracted from the second heat exchange medium by means of the cooling device is not lost but is beneficially recovered for heating the first heat exchange medium entering the charged adsorption vessel coupled to the heating circuit. This further improves the efficiency of the power generation by the system.

[0015] In an embodiment of the system according to the present invention the system comprises at least two of the sets of adsorption vessels. The system comprises a first heat recovery section in the heating circuit downstream of an adsorption vessel coupled the heating circuit, i.e. downstream of a position wherein a charged adsorption vessel of a set is to be selectively coupled to the heating circuit. The first heat recovery section is configured for selectively coupling, i.e. selectively connecting, in series to the charged adsorption vessel of each of the at least one set not coupled to the heating

circuit and the cooling circuit. The heating circuit is configured for circulating the first heat exchange medium through the at least one coupled adsorption vessel of the first heat recovery section after the first heat exchange medium has passed through the adsorption vessel coupled to the heating circuit. Thereby, the at least one coupled adsorption vessel of the first heat recovery section is pre-heated with residual heat in the first heat exchange medium and consequently the first heat exchange medium is cooled by giving off the residual heat to the at least one coupled adsorption vessel of the first heat recovery section. The system comprises a second heat recovery section in the heating circuit downstream of the first heat recovery section. The second heat recovery section is configured for selectively coupling, i.e. selectively connecting, in series the discharged adsorption vessel of each of the at least one set not coupled to the heating circuit and the cooling circuit. Thereby, the charged adsorption vessel and the discharged adsorption vessel of the same set are coupled at corresponding downstream positions to respectively the first heat recovery section and the second heat recovery section. The heating circuit is configured for circulating the first heat exchange medium through the at least one coupled adsorption vessel of the second heat recovery section after the first heat exchange medium has passed through the at least one coupled adsorption vessel of the first heat recovery section. Thereby, the at least one coupled adsorption vessel of the second heat recovery section is pre-cooled by the at least one coupled adsorption vessel of the second heat recovery section giving off residual heat to the first heat exchange medium and consequently the first heat exchange medium is heated with the residual heat of the at least one coupled adsorption vessel of the second heat recovery section.

[0016] For generating power the system according to this embodiment of the present invention is used as follows. Take a first set, second set and third set, each with a first adsorption vessel and a second adsorption vessel, wherein the adsorbate is adsorbed substantially on the adsorbent bed of the first adsorption vessel of each set. The heat source is coupled to the heating circuit.

[0017] In a first phase of a power generation cycle of the first set the first adsorption vessel of the first set is coupled to the heating circuit and to the first end of the power generation circuit, and the second adsorption vessel of the first set is coupled to the cooling circuit and to the second end of the power generation circuit. The first adsorption vessel of the second set and the third set are coupled to the first heat recovery section of the heating circuit respectively at the first and second downstream position from the first adsorption vessel of the first set. The second adsorption vessel of the second set and the third set are coupled to the second heat recovery section of the heating circuit respectively at the first and second downstream position from the first heat recovery section of the heating circuit. The first heat exchange medium is then circulated through the heating circuit. Thereby, the first heat exchange medium passes first through the first adsorption vessel of the first set for heating the first adsorption vessel of the first set for the purpose of desorbing the adsorbate from the adsorbent bed of the first adsorption vessel of the first set, which desorbed adsorbate then passes through the power generation circuit, thereby generating power, to the second adsorption vessel of the first set where it is adsorbed on the adsorbent bed of the actively cooled second adsorption vessel of the first set. Then, the first heat exchange medium passes through the first adsorption vessel of the second and third set in the first heat recovery section for the purpose of pre-heating the first adsorption vessel of the second and third set with the residual heat in the first heat exchange medium. This cools down the first heat exchange medium, which then passes through the second adsorption vessel of the second and third set in the second heat recovery section for the purpose of pre-cooling the second adsorption vessel of the second and third set by the second adsorption vessel of the second and third set giving off residual heat to the first heat exchange medium, which heats the first heat exchange medium.

[0018] In a first phase of a power generation cycle of the second set the first adsorption vessel of the second set is coupled to the heating circuit and to the first end of the power generation circuit, and the second adsorption vessel of the second set is coupled to the cooling circuit and to the second end of the power generation circuit for the power generation process whereby desorbed adsorbate passes through the power generation circuit from the first adsorption vessel of the second set to the second adsorption vessel of the second set where the desorbed adsorbate is adsorbed on the adsorbent bed of the second adsorption vessel of the second set. The first adsorption vessel of the third set and the second adsorption vessel of the first set are coupled to the first heat recovery section of the heating circuit respectively at the first and second downstream positions for being pre-heated. The second adsorption vessel of the third set and the first adsorption vessel of the first set are coupled to the second heat recovery section of the heating circuit respectively at the first and second downstream positions for being pre-cooled.

[0019] In a first phase of a power generation cycle of the third set the first adsorption vessel of the third set is coupled to the heating circuit and to the first end of the power generation circuit, and the second adsorption vessel of the third set is coupled to the cooling circuit and to the second end of the power generation circuit for the power generation process whereby desorbed adsorbate passes through the power generation circuit from the first adsorption vessel of the third set to the second adsorption vessel of the third set where the desorbed adsorbate is adsorbed on the adsorbent bed of the second adsorption vessel of the third set. The second adsorption vessel of the first and second set are coupled to the first heat recovery section of the heating circuit respectively at the first and second downstream positions for being pre-heated. The first adsorption vessel of the first and second set are coupled to the second heat recovery section of the heating circuit respectively at the first and second downstream positions for being pre-cooled.

[0020] In a second phase of a power generation cycle of the first set the second adsorption vessel of the first set is

coupled to the heating circuit and to the first end of the power generation circuit, and the first adsorption vessel of the first set is coupled to the cooling circuit and to the second end of the power generation circuit for the power generation process whereby desorbed adsorbate passes through the power generation circuit from the second adsorption vessel of the first set to the first adsorption vessel of the first set where the desorbed adsorbate is adsorbed on the adsorbent bed of the first adsorption vessel of the first set. The second adsorption vessel of the second and third set are coupled to the first heat recovery section of the heating circuit respectively at the first and second downstream positions for being pre-heated. The first adsorption vessel of the second and third set are coupled to the second heat recovery section of the heating circuit respectively at the first and second downstream positions for being pre-cooled.

[0021] In a second phase of a power generation cycle of the second set the second adsorption vessel of the second set is coupled to the heating circuit and to the first end of the power generation circuit, and the first adsorption vessel of the second set is coupled to the cooling circuit and to the second end of the power generation circuit for the power generation process whereby desorbed adsorbate passes through the power generation circuit from the second adsorption vessel of the second set to the first adsorption vessel of the second set where the desorbed adsorbate is adsorbed on the adsorbent bed of the first adsorption vessel of the second set. The second adsorption vessel of the third set and the first adsorption vessel of the first set are coupled to the first heat recovery section of the heating circuit respectively at the first and second downstream positions for being pre-heated. The first adsorption vessel of the third set and the second adsorption vessel of the first set are coupled to the second heat recovery section of the heating circuit respectively at the first and second downstream positions for being pre-cooled.

[0022] In a second phase of a power generation cycle of the third set the second adsorption vessel of the third set is coupled to the heating circuit and to the first end of the power generation circuit, and the first adsorption vessel of the third set is coupled to the cooling circuit and to the second end of the power generation circuit for the power generation process whereby desorbed adsorbate passes through the power generation circuit from the second adsorption vessel of the third set to the first adsorption vessel of the third set where the desorbed adsorbate is adsorbed on the adsorbent bed of the first adsorption vessel of the third set. The first adsorption vessel of the first and second set are coupled to the first heat recovery section of the heating circuit respectively at the first and second downstream positions for being pre-heated. The second adsorption vessel of the first and second set are coupled to the second heat recovery section of the heating circuit respectively at the first and second downstream positions for being pre-cooled. After this the power generation process returns back to the first phase of the power generation cycle of the first set and the whole process is repeated.

[0023] The use of a plurality of sets of adsorption vessels in the system according to this embodiment offers the advantage that a phase of a power generation cycle of one of the sets can be performed. In the meantime the charged adsorption vessels of the other sets are already pre-heated in the first heat recovery section, such that when these charged adsorption vessels are coupled to the heating circuit in further phases of the power generation process, less heat and time is required for heating these charged adsorption vessels to the desired temperature for desorbing the adsorbate from the adsorbent bed of these charged adsorption vessels. The first heat recovery section thereby offers the advantage that residual heat in the first heat exchange medium, after having passed through the charged adsorption vessel coupled to the heating circuit, is not lost but is recovered for pre-heating the charged adsorption vessels coupled to the first heat recovery section. Thereby, the residual heat in the first heat exchange medium is transferred to the charged adsorption vessels coupled to the first heat recovery section, which transfer of residual heat cools off the first heat exchange medium. In the meantime the discharged adsorption vessels of the others sets are already pre-cooled in the second heat recovery section, such that when these discharged adsorption vessels are coupled to the cooling circuit in further phases of the power generation process, less active cooling and time is required for cooling these discharged adsorption vessels to the desired temperature for adsorbing received adsorbate on the adsorbent bed of these discharged adsorption vessels. The second heat recovery section thereby offers the advantage that residual heat in the discharged adsorption vessels coupled to the second heat recovery section is not lost but is recovered for already partially heating the first heat exchange medium before the first heat exchange medium is further heated by means of the heat source before the first heat exchange medium again enters the charged adsorption vessel coupled to the heating circuit. Thereby, the residual heat in the discharged adsorption vessels coupled to the second heat recovery section is transferred to the cooled down first heat exchange medium coming from the first heat recovery section, which transfer of residual heat pre-cools the discharged adsorption vessels coupled to the second heat recovery section. This further improves the efficiency of the power generation process performed by the system.

[0024] In an embodiment of the system according to the present invention the power generation device comprises an expansion turbine coupled to a generator, such that when the adsorbate passes from the adsorption vessel coupled to the heating circuit to the adsorption vessel coupled to the cooling circuit through the expansion turbine work is generated for driving the generator to generate power.

[0025] In an embodiment of the system according to the present invention the cooling device comprises a reservoir for the second heat exchange medium in the cooling circuit upstream of the coupled adsorption vessel. The cooling device comprises a vapour recompression device configured for extracting and compressing vapour of the second heat exchange medium in the reservoir for cooling the second heat exchange medium in the reservoir.

[0026] In an embodiment of the system according to the present invention the system comprises a first heat exchanger coupling the heating circuit to the heat source for heating the first heat exchange medium entering the adsorption vessel coupled to the heating circuit.

[0027] In an embodiment of the system according to the present invention the system comprises a second heat exchanger coupling the cooling device to the heating circuit for heating with heat extracted from the second heat exchange medium the first heat exchange medium entering the adsorption vessel coupled to the heating circuit.

[0028] The present invention also provides a method for operating the system according to the present invention. In a first phase of a power generation cycle of a first set of the at least one set of adsorption vessels, in which the adsorbate is adsorbed substantially, i.e. mainly, on the adsorbent bed of the first adsorption vessel of the first set, the method comprises the following steps. Optionally, in the first phase of the power generation cycle of the first set the method comprises the step of pre-heating the first adsorption vessel of the first set and/or pre-cooling the second adsorption vessel of the first set. In the first phase of the power generation cycle of the first set the method comprises the step of coupling, i.e. connecting, a heat source to the heating circuit. In the first phase of the power generation cycle of the first set the method comprises the step of coupling, i.e. connecting, the first adsorption vessel of the first set to the first end of the power generation circuit and the second adsorption vessel of the first set to the second end of the power generation circuit. In the first phase of the power generation cycle of the first set the method comprises the step of coupling, i.e. connecting, the first adsorption vessel of the first set to the heating circuit and the second adsorption vessel of the first set to the cooling circuit. In the first phase of the power generation cycle of the first set the method comprises the step of heating the first adsorption vessel of the first set by circulating the first heat exchange medium in the heating circuit through the first adsorption vessel of the first set for desorbing the adsorbate from the adsorbent bed of the first adsorption vessel of the first set. In the first phase of the power generation cycle of the first set the method comprises the step of passing the desorbed adsorbate through the power generation circuit from the first adsorption vessel of the first set to the second adsorption vessel of the first set through the power generation device for generating power. In the first phase of the power generation cycle of the first set the method comprises the step of cooling the second adsorption vessel of the first set by circulating the second heat exchange medium in the cooling circuit through the second adsorption vessel of the first set for adsorbing the adsorbate, i.e. the adsorbate received from the first adsorption vessel of the first set via the power generation circuit, on the adsorbent bed of the second adsorption vessel of the first set.

[0029] In an embodiment of the method according to the present invention in a second phase of the power generation cycle of the first set, after the adsorbate has been adsorbed substantially on the adsorbent bed of the second adsorption vessel of the first set, the method comprises the following steps. Optionally, in the second phase of the power generation cycle of the first set the method comprises the step of pre-heating the second adsorption vessel of the first set and/or pre-cooling the first adsorption vessel of the first set. In the second phase of the power generation cycle of the first set the method comprises the step of coupling, i.e. connecting, the first adsorption vessel of the first set to the second end of the power generation circuit and the second adsorption vessel of the first set to the first end of the power generation circuit. In the second phase of the power generation cycle of the first set the method comprises the step of coupling, i.e. connecting, the first adsorption vessel of the first set to the cooling circuit and the second adsorption vessel of the first set to the heating circuit. In the second phase of the power generation cycle of the first set the method comprises the step of heating the second adsorption vessel of the first set by circulating the first heat exchange medium in the heating circuit through the second adsorption vessel of the first set for desorbing the adsorbate from the adsorbent bed of the second adsorption vessel of the first set. In the second phase of the power generation cycle of the first set the method comprises the step of passing the desorbed adsorbate through the power generation circuit from the second adsorption vessel of the first set to the first adsorption vessel of the first set through the power generation device for generating power. In the second phase of the power generation cycle of the first set the method comprises the step of cooling the first adsorption vessel of the first set by circulating the second heat exchange medium in the cooling circuit through the first adsorption vessel for adsorbing the adsorbate, i.e. the adsorbate received from the second adsorption vessel of the first set via the power generation circuit, on the adsorbent bed of the first adsorption vessel of the first set.

[0030] In an embodiment of the method according to the present invention the system comprises at least one further set. The adsorbate is also adsorbed substantially on the adsorbent bed of the first adsorption vessel of the at least one further set. The system also comprises the first heat recovery section and the second heat recovery section. The method also comprises the following steps in the first phase of the power generation cycle of the first set. In the first phase of the power generation cycle of the first set the method also comprises the step of coupling, i.e. connecting, the first adsorption vessel of each of the at least one further set to the first heat recovery section and the second adsorption vessel of each of the at least one further set to the second heat recovery section. Thereby, the first adsorption vessel and the second adsorption vessel of a corresponding further set are coupled at corresponding downstream positions to respectively the first heat recovery section and the second heat recovery section. In the first phase of the power generation cycle of the first set the method also comprises the step of pre-heating the first adsorption vessel of each set in the first heat recovery section by circulating the first heat exchange medium in the heating circuit through the first adsorption vessel of each set in the first heat recovery section after the first heat exchange medium has passed through the first adsorption vessel of the first set

coupled to the heating circuit, thereby cooling the first heat exchange medium. In the first phase of the power generation cycle of the first set the method also comprises the step of pre-cooling the second adsorption vessel of each set in the second heat recovery section by circulating the first heat exchange medium in the heating circuit through the second adsorption vessel of each set in the second heat recovery section after the first heat exchange medium has passed through the first adsorption vessel of each set in the first heat recovery section, thereby heating the first heat exchange medium.

[0031] In an embodiment of the method according to the present invention the method comprises after the first phase of the power generation cycle of the first set a first phase of a power generation cycle of a second set of the least two sets of adsorption vessels. Thereby, the second set is the set of adsorption vessels at the first downstream position in the first heat recovery section and the second heat recovery section. The first phase of the power generation cycle of the second set comprises decoupling, i.e. disconnecting, the first adsorption vessel and the second adsorption vessel of the first set from the power generation circuit, i.e. from respectively the first end and the second end of the power generation circuit. The first phase of the power generation cycle of the second set comprises decoupling, i.e. disconnecting, the first adsorption vessel of the first set from the heating circuit and the second adsorption vessel of the first set from the cooling circuit. The first phase of the power generation cycle of the second set comprises decoupling, i.e. disconnecting, the first adsorption vessel of the second set from the first heat recovery section and the second adsorption vessel of the second set from the second heat recovery section. The first phase of the power generation cycle of the second set comprises coupling, i.e. connecting, the first adsorption vessel of the second set to the first end of the power generation circuit and the second adsorption vessel of the second set to the second end of the power generation circuit. The first phase of the power generation cycle of the second set comprises coupling, i.e. connecting, the first adsorption vessel of the second set to the heating circuit and the second adsorption vessel of the second set to the cooling circuit. The first phase of the power generation cycle of the second set comprises coupling, i.e. connecting, the first adsorption vessel of the first set to the first heat recovery section at the last downstream position and the second adsorption vessel of the first set to the second heat recovery section at the last downstream position. The first phase of the power generation cycle of the second set comprises heating the first adsorption vessel of the second set by circulating the first heat exchange medium in the heating circuit through the first adsorption vessel of the second set for desorbing the adsorbate from the adsorbent bed of the first adsorption vessel of the second set. The first phase of the power generation cycle of the second set comprises passing the desorbed adsorbate through the power generation circuit from the first adsorption vessel of the second set to the second adsorption vessel of the second set through the power generation device for generating power. The first phase of the power generation cycle of the second set comprises cooling the second adsorption vessel of the second set by circulating the second heat exchange medium in the cooling circuit through the second adsorption vessel of the second set for adsorbing the adsorbate, i.e. the adsorbate received from the first adsorption vessel of the second set via the power generation circuit, on the adsorbent bed of the second adsorption vessel of the second set. The first phase of the power generation cycle of the second set comprises pre-heating the first adsorption vessel of each set in the first heat recovery section by circulating the first heat exchange medium in the heating circuit through the first adsorption vessel of each set in the first heat recovery section after the first heat exchange medium has passed through the first adsorption vessel of the second set coupled to the heating circuit, thereby cooling the first heat exchange medium. The first phase of the power generation cycle of the second set comprises pre-cooling the second adsorption vessel of each set in the second heat recovery section by circulating the first heat exchange medium in the heating circuit through the second adsorption vessel of each set in the second heat recovery section after the first heat exchange medium has passed through the first adsorption vessel of each set in the first heat recovery section, thereby heating the first heat exchange medium.

Brief description of the drawings

[0032] The invention will be further elucidated by means of the following description and the appended figures.

Figure 1 shows a schematical representation of a system for generating power from a heat source according to an embodiment of the present invention.

Figure 2 shows a system for generating power from a heat source according to an embodiment of the present invention.

Figure 3 shows a detail of the system of Figure 2.

Figure 4 illustrates the first phase of the power generation cycle of the first set of adsorption vessels of the system of Figure 2.

Figure 5 illustrates the first phase of a power generation cycle of the second set of adsorption vessels of the system of Figure 2.

Figure 6 illustrates the second phase of a power generation cycle of the first set of adsorption vessels of the system of Figure 2.

Figure 7 illustrates the second phase of a power generation cycle of the second set of adsorption vessels of the system of Figure 2.

Modes for carrying out the invention

[0033] The present invention will be described with respect to particular embodiments and with reference to certain drawings but the invention is not limited thereto but only by the claims. The drawings described are only schematic and are non-limiting. In the drawings, the size of some of the elements may be exaggerated and not drawn on scale for illustrative purposes. The dimensions and the relative dimensions do not necessarily correspond to actual reductions to practice of the invention.

[0034] Furthermore, the terms first, second, third and the like in the description and in the claims, are used for distinguishing between similar elements and not necessarily for describing a sequential or chronological order. The terms are interchangeable under appropriate circumstances and the embodiments of the invention can operate in other sequences than described or illustrated herein.

[0035] Moreover, the terms top, bottom, over, under and the like in the description and the claims are used for descriptive purposes and not necessarily for describing relative positions. The terms so used are interchangeable under appropriate circumstances and the embodiments of the invention described herein can operate in other orientations than described or illustrated herein.

[0036] The term "comprising", used in the claims, should not be interpreted as being restricted to the means listed thereafter; it does not exclude other elements or steps. It needs to be interpreted as specifying the presence of the stated features, integers, steps or components as referred to, but does not preclude the presence or addition of one or more other features, integers, steps or components, or groups thereof. Thus, the scope of the expression "a device comprising means A and B" should not be limited to devices consisting only of components A and B. It means that with respect to the present invention, the only relevant components of the device are A and B.

[0037] Figure 1 shows a schematical representation of an embodiment of a system 100 according to the present invention for generating power from a heat source 1000. Preferably, the heat source 1000 is waste heat from other processes. The system 100 according to the present invention may however also be used with other heat sources 100, and the heat source 100 may also have temperatures equal to and above 100 °C. A practical implementation of an embodiment of a system 100 according to the present invention for generating power from a heat source 1000 is illustrated in Figure 2. A detail of an adsorption vessel 210 of the system 100 of Figure 2 is shown in Figure 3. The system 100 will now be explained with reference to Figure 1, but for some features reference will be made to Figures 2 and 3, which show some more detail.

[0038] The system 100, as shown in Figure 1, comprises four sets A-D of adsorption vessels 210. In alternative embodiments more or less sets A-D of adsorption vessels 210 may however be used, such as for example two sets A-B in the system 100 of Figure 2. Each set A-D comprises a first adsorption vessel 210-A1, 210-B1, 210-C1, 210-D1 and a second adsorption vessel 210-A2, 210-B2, 210-C2, 210-D2. Preferably, all the adsorption vessels 210 are arranged in the same manner. Each adsorption vessel 210 comprises an adsorbent bed 220, as can be seen in Figures 2 and 3. The adsorbent bed 220 is a structure of an adsorbent material suitable for adsorbing and desorbing an adsorbate. Preferably, the adsorbent bed 220 has a large external surface for adsorbing and desorbing an adsorbate. The adsorbent material may for example be activated carbon, activated alumina, silica gel, zeolites, clay and metal organic frameworks, but it should be clear that any other suitable adsorbent material known to the skilled person can be used. Each adsorption vessel 210 also comprises an internal heat exchanger 230, as can be seen in Figures 2 and 3. Through the internal heat exchanger 230 a heat exchange medium can be passed for heating or cooling the adsorption vessel 210. The adsorption vessel 210 is provided with a first heat exchange medium port 243 and a second heat exchange medium port 244, as can be seen in Figures 2 and 3. The first heat exchange medium port 243 and the second heat exchange medium port 244 are provided for connecting a heat exchange medium conduit thereto for passing a heat exchange medium through the internal heat exchanger 230.

[0039] The system 100 also comprises an adsorbate that is suitable for being adsorbed on and desorbed from the adsorbent bed 220 of each adsorption vessel 210. The adsorbate may for example be nitrogen, hydrogen or helium, but it should be clear that any other suitable adsorbate known to the skilled person can be used. Preferably, the adsorbate is an adsorbate with a low heat of adsorption to increase the efficiency of the power generation process by means of the system 100. For the purpose of the power generation process the adsorbate is adsorbed substantially, i.e. mainly, on the adsorbent bed 220 of one of the adsorption vessels 210 of a set A-D, referred to as a charged adsorption vessel 210, such that the adsorbate can be desorbed from the adsorbent bed 220 of this charged adsorption vessel and passed to the other adsorption vessel 210 of the same set A-D, referred to as a discharged adsorption vessel 210, where it can be adsorbed on the adsorbent bed 220 of the discharged adsorption vessel 210. To be able to pass the desorbed adsorbate from the charged adsorption vessel 210 to the discharged adsorption vessel 210 each adsorption vessel 210 is, as can be seen in Figures 2 and 3, provided with an adsorbate outlet 241 via which adsorbate can leave the adsorption vessel 210 and an adsorbate inlet 242 via which adsorbate can enter the adsorption vessel 210. In Figure 1, which shows the arrangement of the system 100 in a first phase of a power generation cycle of the first set A of adsorption vessels 210, the adsorbate is adsorbed substantially on the adsorbent bed 220 of the first adsorption vessel 210-A1, 210-B1, 210-C1, 210-D1 of each set A-D, which form as such the charged adsorption vessels 210. At this stage only a small residual amount of adsorbate is

adsorbed on the adsorbent bed 220 of the second adsorption vessel 210-A2, 210-B2, 210-C2, 210-D2 of each set A-D, which form as such the discharged adsorption vessels 210.

[0040] The system 100 further comprises a heating circuit 300, a cooling circuit 400 and a power generation circuit 500.

[0041] The heating circuit 300 is configured for being selectively coupled primary to the charged adsorption vessel 210 of a set A-D. The heating circuit 300 is configured for heating this primary coupled charged adsorption vessel 210 at least with the heat from the heat source 1000, such that the adsorbate is desorbed from the adsorbent bed 220 of the primary coupled charged adsorption vessel 210.

[0042] The cooling circuit 400 is configured for being selectively coupled to the discharged adsorption vessel 210 of the same set A-D of which the charged adsorption vessel 210 is selectively coupled primary to the heating circuit 300. The cooling circuit 400 is configured for actively cooling the coupled discharged adsorption vessel 210 to a predetermined temperature below the temperature of the heat source 1000. Preferably, the predetermined temperature is at least 50°C, preferably at least 52°C, more preferably at least 54°C, even more preferably at least 56°C, yet even more preferably at least 58°C and most preferably at least 60°C below the temperature of the heat source 1000, and/or the predetermined temperature is at most 90°C, preferably at most 88°C, more preferably at most 86°C, even more preferably at most 84°C, yet even more preferably at most 82°C and most preferably at most 80°C below the temperature of the heat source 1000. More preferably, the difference between the temperature of the heat source 1000 and ambient temperature is thereby at most 80°C, preferably at most 76°C, more preferably at most 72°C, even more preferably at most 68°C, yet even more preferably at most 64°C and most preferably at most 60°C.

[0043] The power generation circuit 500 is configured for being selectively coupled at a first end 501 to the charged adsorption vessel 210 coupled primary to the heating circuit 300 and at a second end 502 to the discharged adsorption vessel 210 coupled to the cooling circuit 400. The power generation circuit 500 is configured for passing the adsorbate that is desorbed from the adsorbent bed 220 of the charged adsorption vessel 210 primary coupled to the heating circuit 300 to the discharged adsorption vessel 210 coupled to the cooling circuit 400. The power generation circuit 500 comprises a power generation device 510 that is configured for generating power when the desorbed adsorbate passes through the power generation circuit 500 from the adsorption vessel 210 coupled to the heating circuit 300 to the adsorption vessel 210 coupled to the cooling circuit 400. In the shown embodiments the power generation device 510 comprises an expansion turbine 512 coupled to a generator (not shown) such that when the adsorbate passes from the adsorption vessel 210 coupled primary to the heating circuit 300 to the adsorption vessel 210 coupled to the cooling circuit 400 through the expansion turbine 512 work is generated for driving the generator to generate power. It should however be clear that in alternative embodiments any other suitable power generation device 510 known to the skilled person can be used.

[0044] Once the desorbed adsorbate has passed through the power generation device 510 it is received in the adsorption vessel 210 coupled to the cooling circuit 400, which is actively cooled for adsorbing the received desorbed adsorbate on its adsorbent bed 220. Hereby, the active cooling offers the advantage that the difference in temperature between the charged adsorption vessel 210 primary coupled to the heating circuit 300, which is heated by at least the heat of the heat source 1000, and the temperature of the discharged adsorption vessel 210 coupled to the cooling circuit 400 can be increased. Since, according to the Carnot's theorem, the maximum heat-to-power efficiency of the power generation by the system 100 is determined by this difference, the increase in the temperature difference between the charged adsorption vessel 210 coupled to the heating circuit 300 and the discharged adsorption vessel 210 coupled to the cooling circuit 400 also increases the maximum heat-to-power efficiency and thus the efficiency of the power generation by the system 100. The active cooling of the discharged adsorption vessel 210 also offers the advantage that the desired temperature of the discharged adsorption vessel 210 can be reached more quickly, which speeds up the power generation process and thus increases its efficiency.

[0045] Now, the heating circuit 300 and the cooling circuit 400 will be discussed in further detail.

[0046] The heating circuit 300 comprises a first reservoir 810, i.e. a hot buffer, which contains a first heat exchange medium. The first heat exchange medium may for example be a refrigerant, such as R-1336mz, R-227ea, R1233zd or R1234yf, but it should be clear that any other suitable heat exchange medium known to the skilled person can be used.

[0047] The heating circuit 300 further comprises a first pump 710 that is configured for pumping the first heat exchange medium from the first reservoir 810 through the heating circuit 300 in a predetermined first flow direction until the first heat exchange medium returns back at the first reservoir 810.

[0048] In the predetermined first flow direction downstream of the first pump 710, the heating circuit 300 comprises a first heat exchanger 610 that is coupled to the heat source 1000 for heating up the first heat exchange medium by means of the heat from the heat source 1000. Therefore, the first heat exchanger 610 is coupled to an external circuit that is provided with a pump 730 for circulating a heat exchange medium coming from the heat source 1000, where it was heated by means of the heat of the heat source 1000, through the first heat exchanger 610 and back towards the heat source 1000.

[0049] In the predetermined first flow direction downstream of the first heat exchanger 610, the heating circuit 300 further comprises a second heat exchanger 620. The second heat exchanger 620 is used for further heating the first heat exchange medium with heat recovered from the cooling circuit 400, which will be discussed in further detail below.

[0050] In the predetermined first flow direction downstream of the second heat exchanger 620, the heating circuit 300 is

then selectively coupled to the charged adsorption vessel 210 of one of the sets A-D for performing a power generation cycle phase of this set A-D. In figure 1, which illustrates the arrangement of the system 100 in the first phase of the power generation cycle of the first set A, the heating circuit 300 is therefore selectively coupled to the first adsorption vessel 210-A1 of the first set A, i.e. the charged absorption vessel 210 of the first set A. The heating circuit 300 is thereby coupled to the internal heat exchanger 230 of the coupled charged adsorption vessel 210 for passing the first heat exchange medium through the internal heat exchanger 230 of the coupled charged adsorption vessel 210. Passing through the internal heat exchanger 230 of the coupled charged adsorption vessel 210, the first heat exchange medium, which was previously heated by means of the heat from the heat source 1000 via the first heat exchanger 610 and further heated by means of heat recovered from the cooling circuit 400 via the second heat exchanger 620, gives off its heat to the adsorbent bed 220 of the coupled charged adsorption vessel 210, which causes the adsorbate to be desorbed from the adsorbent bed 220 of the coupled charged adsorption vessel 210.

[0051] In the predetermined first flow direction downstream of the charged adsorption vessel 210 that is primary coupled to the heating circuit 300, the heating circuit 300 comprises a first heat recovery section 310. In the first heat recovery section 310 the heating circuit 300 is selectively coupled in series to the charged adsorption vessels 210 of the other sets A-D, i.e. the sets A-D of which the charged adsorption vessel 210 is not primary coupled to the heating circuit 300.

[0052] In figure 1, which illustrates the arrangement of the system 100 in the first phase of the power generation cycle of the first set A, the heating circuit 300 is thereby selectively coupled in the first heat recovery section 310 at a first downstream position to the first adsorption vessel 210-B1 of the second set B, at a second downstream position to the first adsorption vessel 210-C1 of the third set C and at a third downstream position to the first adsorption vessel 210-D1 of the fourth set D, i.e. the charged absorption vessels 210 of the second, third and fourth set B-C.

[0053] In the first heat recovery section 310 the heating circuit 300 is coupled to the internal heat exchanger 230 of the coupled charged adsorption vessels 210 in the first heat recovery section 310 for passing the first heat exchange medium through the internal heat exchanger 230 of said coupled charged adsorption vessels 210. Thereby, the first heat exchange medium gives off its residual heat to the coupled charged adsorption vessels 210 in the first heat recovery section 310. This pre-heats the coupled charged adsorption vessels 210 in the first heat recovery section 310 with the residual heat in the first heat exchange medium and consequently cools the first heat exchange medium by giving off its residual heat to the coupled charged adsorption vessels 210 in the first heat recovery section 310. Hence, in the first heat recovery section 310 the residual heat in the first heat exchange medium is beneficially recovered for pre-heating the coupled charged adsorption vessels 210 in the first heat recovery section 310.

[0054] The adsorption vessels 210 that are selectively coupled to the heating circuit 300 in the first heat recovery section 310 are adsorption vessels 210 that have been selectively coupled to the cooling circuit 400 in previous phases of the power generation process of the system 100, and these adsorption vessels 210 are intended for being selectively coupled primary to the heating circuit 300 in following phases of the power generation process 100 of the system 100. Hence, at the start of a next phase, as indicated by the arrows in Figure 1, the adsorption vessel 210 at the first downstream position of the first heat recovery section 310 is coupled primary to the heating circuit 300, each of the remaining adsorption vessels 210 of the first heat recovery section 310 is moved one position upstream in the first heat recovery section 310, and the adsorption vessel 210 coupled to the cooling circuit 400 is coupled to the first heat recovery section 310 at the last downstream position.

[0055] The first heat recovery section 310 hereby offers the advantage that the adsorption vessels 210, which have been coupled to and cooled by the cooling circuit 400 in previous phases of the power generation process of the system 100, are pre-heated in the first heat recovery section 310 before they are coupled to the heating circuit 300 in later phases of the power generation process of the system 100. In this way, when these adsorption vessels 210 are coupled to the heating circuit 300 in later phases of the power generation process of the system 100, less heat and time will be required for heating these adsorption vessels 210 to the desired temperature for desorbing the adsorbate from the adsorbent bed 220 of these adsorption vessels 210. This improves the efficiency of the power generation process performed by the system 100.

[0056] The first heat exchange medium being cooled in the first heat recovery section 310 is thereby beneficial for using the first heat exchange medium for cooling adsorption vessels 210 further downstream in a second heat recovery section 320 of the heating circuit 300, as will be explained in further detail below.

[0057] In the predetermined first flow direction downstream of the first heat recovery section 310, the heating circuit 300 comprises the second heat recovery section 320. In the second heat recovery section 320 the heating circuit 300 is selectively coupled in series to the discharged adsorption vessels 210 of the other sets A-D, i.e. the sets A-D of which the discharged adsorption vessel 210 is not coupled to the cooling circuit 400. Thereby, the charged adsorption vessel 210 and the discharged adsorption vessel 210 of the same set A-D are coupled at corresponding downstream positions to respectively the first heat recovery section 310 and the second heat recovery section 320.

[0058] In figure 1, which illustrates the arrangement of the system 100 in the first phase of the power generation cycle of the first set A, the heating circuit 300 is thereby thus selectively coupled in the second heat recovery section 320 at a first downstream position to the second adsorption vessel 210-B2 of the second set B, at a second downstream position to the second adsorption vessel 210-C2 of the third set C and at a third downstream position to the second adsorption vessel 210-

D2 of the fourth set D, i.e. the discharged absorption vessels 210 of the second, third and fourth set B-C.

[0059] In the second heat recovery section 320 the heating circuit 300 is coupled to the internal heat exchanger 230 of the coupled discharged adsorption vessels 210 in the second heat recovery section 320 for passing the first heat exchange medium through the internal heat exchanger 230 of said coupled discharged adsorption vessels 210. Thereby, the coupled discharged adsorption vessels 210 give off their residual heat to the first heat exchange medium. This pre-cools the coupled discharged adsorption vessels 210 in the second heat recovery section 320 by giving off their residual heat to the first heat exchange medium and consequently heats the first heat exchange medium with the residual heat of the coupled discharged adsorption vessels 210 in the second heat recovery section 320.

[0060] The adsorption vessels 210 that are selectively coupled to the heating circuit 300 in the second heat recovery section 320 are adsorption vessels 210 that have been selectively coupled primary to the heating circuit 300 in previous phases of the power generation process of the system 100, and these adsorption vessels 210 are intended for being selectively coupled to the cooling circuit 400 in following phases of the power generation process 100 of the system 100. At the start of a next phase, as indicated by the arrows in Figure 1, the adsorption vessel 210 at the first downstream position of the second heat recovery section 320 is coupled to the cooling circuit 400, each of the remaining adsorption vessels 210 of the second heat recovery section 320 is moved one position upstream in the second heat recovery section 320, and the adsorption vessel 210 primary coupled to the heating circuit 300 is coupled to the second heat recovery section 320 at the last downstream position.

[0061] The second heat recovery section 320 hereby offers the advantage that the adsorption vessels 210, which have been coupled primary to and heated by the heating circuit 300 in previous phases of the power generation process of the system 100, are pre-cooled in the second heat recovery section 320 by giving off their residual heat to the first heat exchange medium before they are coupled to the cooling circuit 400 in later phases of the power generation process of the system 100. In this way, when these adsorption vessels 210 are coupled to the cooling circuit 400 in later phases of the power generation process of the system 100, less active cooling and time will be required for cooling these adsorption vessels 210 to the desired temperature for adsorbing received adsorbate on the adsorbent bed 220 of these adsorption vessels 210. This improves the efficiency of the power generation process performed by the system 100.

[0062] After the first heat exchange medium has passed through the coupled adsorption vessels 210 in the second heat recovery section, the first heat exchange medium is returned in the first flow direction to the first reservoir 810 for being re-used.

[0063] The first heat exchange medium being heated in the second heat recovery section 320 is thereby beneficial for re-using the first heat exchange medium for heating the adsorption vessel 210 coupled primary to the heating circuit 300. In this way, less heat and time will be required for heating the first heat exchange medium again to the desired temperature by means of the heat of heat source 1000 via the first heat exchanger 610 and the heat recovered from the cooling circuit 400 via the second heat exchanger 620. Hence, in the second heat recovery section 320 the residual heat in the adsorption vessels 210, which have been coupled primary to and heated by the heating circuit 300 in previous phases of the power generation process of the system 100, is beneficially recovered for pre-heating the first heat exchange medium.

[0064] The cooling circuit 300 comprises a second reservoir 820, i.e. a cold buffer, which contains a second heat exchange medium. The second heat exchange medium may for example be a refrigerant, such as R-1336mz, R-227ea, R1233zd or R1234yf, but it should be clear that any other suitable heat exchange medium known to the skilled person can be used. The second reservoir 820 forms part of a cooling device 410 of the system 100 that is configured for actively cooling the second heat exchange medium in the second reservoir 820. For actively cooling the second heat exchange medium, the cooling device 410 comprises a vapour recompression device 412 that is configured for extracting and compressing vapour of the second heat exchange medium in the second reservoir 820. The cooling device 410 forms part of a heat recovery circuit of the system 100 that couples the cooling device 410 to the heating circuit 300 via the second heat exchanger 620. In this way the heat in the compressed vapour of the second heat exchange medium leaving the vapour recompression device can be transferred to the first heat exchange medium in the heating circuit 300 via the second heat exchanger 620 to aid in heating the first heat exchange medium entering the charged adsorption vessel 210 primary coupled to the heating circuit 300. After passing through the second heat exchanger 620 the compressed vapour of the second heat exchange medium, which has been cooled down by giving off its heat to the first heat exchange medium of the heating circuit 300 in the second heat exchanger 620, is returned to the cooling circuit 400.

[0065] The cooling circuit 400 further comprises a second pump 720 that is configured for pumping the second heat exchange medium from the second reservoir 820 through the cooling circuit 400 in a predetermined second flow direction until the second heat exchange medium returns back at the second reservoir 820.

[0066] In the predetermined second flow direction downstream of the second pump 720, the cooling circuit 400 is then selectively coupled to the discharged adsorption vessel 210 of the same set A-D of which the charged adsorption vessel 210 is selectively coupled primary to the heating circuit 300 for performing a power generation cycle phase of this set A-D. In figure 1, which illustrates the arrangement of the system 100 in the first phase of the power generation cycle of the first set A, the cooling circuit 400 is therefore selectively coupled to the second adsorption vessel 210-A2 of the first set A, i.e. the discharged absorption vessel 210 of the first set A. The cooling circuit 400 is thereby coupled to the internal heat exchanger

230 of the coupled discharged adsorption vessel 210 for passing the second heat exchange medium through the internal heat exchanger 230 of the coupled discharged adsorption vessel 210. Passing through the internal heat exchanger 230 of the coupled discharged adsorption vessel 210, the second heat exchange medium, which was previously actively cooled by means of the cooling device 410, extracts heat from and thereby cools the adsorbent bed 220 of the coupled discharged adsorption vessel 210, which causes the adsorbate received from the adsorption vessel 210 coupled to the heating circuit 300 via the power generation circuit 500 to be adsorbed on the adsorbent bed 220 of the coupled discharged adsorption vessel 210.

[0067] After the second heat exchange medium has passed through the coupled adsorption vessel 210, the second heat exchange medium is returned in the second flow direction to the second reservoir 820 for being re-used.

[0068] The power generation process performed by the system 100 will now be discussed on the hand of Figure 1 and on the hand of Table 1, shown below. Table 1 shows for each of the phases of the power generation process the arrangement of the different adsorption vessels 210 in the system 100. Hereby, H0 refers to the heating circuit, P1 to the first end 501 of the power generation circuit 500, R11 to the first downstream position in the first heat recovery section 310, R12 to the second downstream position in the first heat recovery section 310, R13 to the third downstream position in the first heat recovery section 310, R21 to the first downstream position in the second heat recovery section 320, R22 to the second downstream position in the second heat recovery section 320, R23 to the third downstream position in the second heat recovery section 320, C0 to the cooling circuit and, P2 to the second end 502 of the power generation circuit 500.

Table 1: Arrangement of the adsorption vessels 210 at each phase of the power generation process of system 100 of Figure 1.

Set	Phase	H0/P1	R11	R12	R13	R21	R22	R23	C0/P2
A	1	A1	B1	C1	D1	B2	C2	D2	A2
B	1	B1	C1	D1	A2	C2	D2	A1	B2
C	1	C1	D1	A2	B2	D2	A1	B1	C2
D	1	D1	A2	B2	C2	A1	B1	C1	D2
A	2	A2	B2	C2	D2	B1	C1	D1	A1
B	2	B2	C2	D2	A1	C1	D1	A2	B1
C	2	C2	D2	A1	B1	D1	A2	B2	C1
D	2	D2	A1	B1	C1	A2	B2	C2	D1

[0069] In a first phase of a power generation cycle of the first set A the adsorption vessels 210 are arranged in the system 100 as shown in Figure 1 and as indicated in the first row of Table 1. Hereby, the first adsorption vessel 210-A1 of the first set A is coupled primary to the heating circuit 300 and to the first end 501 of the power generation circuit 500, and the second adsorption vessel 210-A2 of the first set A is coupled to the cooling circuit 400 and to the second end 502 of the power generation circuit 500. The first adsorption vessel 210-B1, 210-C1, 210-D1 of the second set B, third set C and fourth set D are coupled to the first heat recovery section 310 of the heating circuit 300 respectively at the first, second and third downstream position of the first heat recovery section 310. The second adsorption vessel 210-B2, 210-C2, 210-D2 of the second set B, third set C and fourth set D are coupled to the second heat recovery section 320 of the heating circuit 300 respectively at the first, second and third downstream position of the second heat recovery section 320.

[0070] The first heat exchange medium is then circulated through the heating circuit 300. Thereby, the first heat exchange medium passes first through the first adsorption vessel 210-A1 of the first set A for heating the first adsorption vessel 210-A1 of the first set A for the purpose of desorbing the adsorbate from the adsorbent bed 220 of the first adsorption vessel 210-A1 of the first set A, which desorbed adsorbate then passes through the power generation circuit 500, thereby generating power, to the second adsorption vessel 210-A2 of the first set A where it is adsorbed on the adsorbent bed 220 of the second adsorption vessel 210-A2 of the first set A, which is actively cooled by means of second heat exchange medium in the cooling circuit 400. Then, the first heat exchange medium passes through the first adsorption vessel 210-B1, 210-C1, 210-D1 of the second set B, third set C and fourth set D in the first heat recovery section 310 for the purpose of pre-heating the first adsorption vessel 210-B1, 210-C1, 210-D1 of the second set B, third set C and fourth set D with the residual heat in the first heat exchange medium. This also cools down the first heat exchange medium, which then passes through the second adsorption vessel 210-B2, 210-C2, 210-D2 of the second set B, third set C and fourth set D in the second heat recovery section 320 for the purpose of pre-cooling the second adsorption vessel 210-B2, 210-C2, 210-D2 of the second set B, third set C and fourth set D by the second adsorption vessel 210-B2, 210-C2, 210-D2 of the second set B, third set C and fourth set D giving off residual heat to the first heat exchange medium, which heats the first heat exchange medium.

[0071] Next, a first phase of a power generation cycle of the second set B is started, in which phase the adsorption vessels 210 are arranged in the system 100 as indicated in the second row of Table 1. Hereby, the first adsorption vessel 210-B1 of the second set B is coupled primary to the heating circuit 300 and to the first end 501 of the power generation

circuit 500, and the second adsorption vessel 210-B2 of the second set B is coupled to the cooling circuit 400 and to the second end 502 of the power generation circuit 500 for the power generation process whereby desorbed adsorbate passes through the power generation circuit 500 from the first adsorption vessel 210-B1 of the second set B to the second adsorption vessel 210-B2 of the second set B where the desorbed adsorbate is adsorbed on the adsorbent bed 220 of the second adsorption vessel 210-B2 of the second set B. The first adsorption vessel 210-C1 of the third set C, the first adsorption vessel 210-D1 of the fourth set D and the second adsorption vessel 210-A2 of the first set A are coupled to the first heat recovery section 310 of the heating circuit 310 respectively at the first, second and third downstream positions for being pre-heated. The second adsorption vessel 210-C2 of the third set C, the second adsorption vessel 210-D2 of the fourth set D and the first adsorption vessel 210-A1 of the first set A are coupled to the second heat recovery section 320 of the heating circuit 300 respectively at the first, second and third downstream positions for being pre-cooled.

[0072] Next, a first phase of a power generation cycle of the third set C is started, in which phase the adsorption vessels 210 are arranged in the system 100 as indicated in the third row of Table 1, and then a first phase of a power generation cycle of the fourth set D is started, in which phase the adsorption vessels 210 are arranged in the system 100 as indicated in the fourth row of Table 1.

[0073] Then, the power generation process performed by the system 100 returns back to the first set A of adsorption vessels 210, for which a second phase of the power generation cycle is started, in which phase the adsorption vessels 210 are arranged in the system 100 as indicated in the fifth row of Table 1. This second phase can be referred to as a reverse phase, since in this second phase the adsorbate that was passed previously during the first phase from the first adsorption vessel 210-A1 of the first set A to the second adsorption vessel 210-A2 of the first set A via the power generation circuit 500 for generating power is now returned back from the second adsorption vessel 210-A2 of the first set A to the first adsorption vessel 210-A1 of the first set A via the power generation circuit 500 for generating power.

[0074] Next, a second phase of the power generation cycle of the second set B is started, in which phase the adsorption vessels 210 are arranged in the system 100 as indicated in the sixth row of Table 1, then a second phase of the power generation cycle of the third set C is started, in which phase the adsorption vessels 210 are arranged in the system 100 as indicated in the seventh row of Table 1, and then a second phase of the power generation cycle of the fourth set D is started, in which phase the adsorption vessels 210 are arranged in the system 100 as indicated in the eighth row of Table 1.

[0075] At this stage, the power generation process has cycled through all phases of the power generation cycles of all the sets A-D of adsorption vessels 210, and is repeated by again starting the first phase of the power generation cycle of the first set A of adsorption vessels 210.

[0076] How the system 100 is switched in practice between the different phases of the power generation process will now be discussed on the basis of Figures 2-7. Hereby, Figure 2 shows a practical implementation of an embodiment of a system 100 according to the present invention for generating power from a heat source 1000. The system 100 of Figure 2 comprises the same components as the system 100 of Figure 1. The system 100 of Figure 2 is however only provided with two sets A-B of adsorption vessels 210 instead of four such as in the system 100 of Figure 1. The system 100 of Figure 2 is however operated according to the same principle as the system 100 of Figure 1 for generating power from a heat source 1000. A detail of one of the adsorption vessels 210 of the system 100 of Figure 2 is shown in Figure 3. The different phases of the power generation process performed by means of the system 100 of Figure 2 is illustrated in Figures 4-7, in which the non-used circuits in each respective phase are omitted for illustrative purposes.

[0077] The system 100 of Figure 2 is provided at each adsorption vessel 210 with nine valves 911-912, 921-927, as shown in detail in Figure 3, by means of which the adsorption vessel 210 can be coupled to the heating circuit 300, the cooling circuit 400 and the power generation circuit 500 of the system 100.

[0078] At the adsorbate outlet 241 of each adsorption vessel 210 the system 100 is provided with an adsorbate outlet valve 911 for connecting the adsorbate outlet 241 of the adsorption vessel 210 to the first end 501 of the power generation circuit 500. At the adsorbate inlet 242 of each adsorption vessel 210 the system 100 is provided with an adsorbate inlet valve 912 for connecting the adsorbate inlet 242 of the adsorption vessel 210 to the second end 502 of the power generation circuit 500.

[0079] At the first heat exchange medium port 243 of each adsorption vessel 210 the system 100 is provided with a first heating circuit valve 921, a first cooling circuit valve 922 and a first interconnection valve 923.

[0080] The first heating circuit valve 921 is provided for connecting the first heat exchange medium port 243 of the corresponding adsorption vessel 210 to a return portion of the heating circuit 300, i.e. the portion of the heating circuit 300 downstream of the adsorption vessels 210 coupled the heating circuit 300 via which the first heat exchange medium is returned back to the first reservoir 810 after having passed through the adsorption vessels 210 coupled to the heating circuit 300.

[0081] The first cooling circuit valve 922 is provided for connecting the first heat exchange medium port 243 of the corresponding adsorption vessel 210 to an incoming portion of the cooling circuit 400, i.e. the portion of the cooling circuit 400 upstream of the adsorption vessel 210 coupled to the cooling circuit 400 via which the actively cooled second heat exchange medium is pumped towards the adsorption vessel 210 coupled to the cooling circuit 400 from the second reservoir 820 by means of the second pump 720.

[0082] The first interconnection valve 923 is provided for connecting the first heat exchange medium port 243 of the corresponding adsorption vessel 210 to the second heat exchange medium port 244 of the next downstream adsorption vessel 210 in the heating circuit 300. Hence, the first interconnection valve 923 is used for coupling adsorption vessels 210 in series to each other in the heating circuit 300.

[0083] At the second heat exchange medium port 244 of each adsorption vessel 210 the system 100 is provided with a second heating circuit valve 926, a second cooling circuit valve 927 and a second interconnection valve 925.

[0084] The second heating circuit valve 926 is provided for connecting the second heat exchange medium port 244 of the corresponding adsorption vessel 210 to an incoming portion of the heating circuit 300, i.e. the portion of the heating circuit 300 upstream of the adsorption vessels 210 coupled the heating circuit 300 via which the first heat exchange medium is pumped towards the adsorption vessel 210 coupled primary to the heating circuit 300 from the first reservoir 810 by means of the first pump 710, thereby passing through the first heat exchanger 610 and the second heat exchanger 620 for being heated.

[0085] The second cooling circuit valve 927 is provided for connecting the second heat exchange medium port 244 of the corresponding adsorption vessel 210 to a return portion of the cooling circuit 400, i.e. the portion of the cooling circuit 400 downstream of the adsorption vessel 210 coupled to the cooling circuit 400 via which the second heat exchange medium is returned back to the second reservoir 820 after having passed through the adsorption vessel 210 coupled to the cooling circuit 300.

[0086] The second interconnection valve 925 is provided for connecting the second heat exchange medium port 244 of the corresponding adsorption vessel 210 to the first heat exchange medium port 243 of the previous upstream adsorption vessel 210 in the heating circuit 300. Hence, the second interconnection valve 925 is used for coupling adsorption vessels 210 in series to each other in the heating circuit 300.

[0087] At each adsorption vessel 210 the system 100 is also provided with a bypass valve 924. The bypass valve 924 is provided for bypassing the corresponding adsorption vessel 210 in the heating circuit 300 when said adsorption vessel 210 is coupled to the cooling circuit 400.

[0088] The different phases of the power generation process performed by means of the system 100 of Figure 2 will now be discussed with reference to Figures 4-7, and Tables 2 and 3, shown below. Figure 4 shows the first phase of the power generation cycle of the first set A of adsorption vessels 210-A1, 210-A2 of the system 100, Figure 5 the first phase of the power generation cycle of the second set B of adsorption vessels 210-B1, 210-B2 of the system 100, Figure 6 the second phase of the power generation cycle of the first set A of adsorption vessels 210-A1, 210-A2 of the system 100, and Figure 7 the second phase of the power generation cycle of the second set B of adsorption vessels 210-B1, 210-B2 of the system 100. Table 2 shows for each of the phases of the power generation process of the system 100 the arrangement of the adsorption vessels 210 in the system 100. Hereby, H0 refers to the heating circuit, P1 to the first end 501 of the power generation circuit 500, R1 to the first heat recovery section 310, R2 to the second heat recovery section 320, C0 to the cooling circuit 400 and P2 to the second end 502 of the power generation circuit 500. Table 3 shows for each of the phases of the power generation process of the system 100 the state of the valves 911-912, 921-927 at each of the adsorption vessels 210. Hereby, the number 1 indicates an opened valve 911-912, 921-927 and the number 0 a closed valve 911-912, 921-927.

Table 2: Arrangement of the adsorption vessels 210 at each phase of the power generation process of system 100 of Figure 2.

Set	Phase	H0/P1	R1	R2	C0/P2
A	1	A1	B1	B2	A2
B	1	B1	A2	A1	B2
A	2	A2	B2	B1	A1
B	2	B2	A1	A2	B1

Table 3: Valve states at each phase of the power generation process of the system 100 of Figure 2.

Vessel	Valve	Set A Phase 1	Set B Phase 1	Set A Phase 2	Set B Phase 2
A1	911	1	0	0	0
	912	0	0	1	0
	921	0	1	0	0
	922	0	0	1	0
	923	1	0	0	1
	924	0	0	1	0
	925	0	1	0	1

(continued)

	Vessel	Valve	Set A Phase 1	Set B Phase 1	Set A Phase 2	Set B Phase 2
5		926	1	0	0	0
		927	0	0	1	0
10	A2	911	0	0	1	0
		912	1	0	0	0
		921	0	0	0	1
		922	1	0	0	0
		923	0	1	1	0
		924	1	0	0	0
		925	0	1	0	1
		926	0	0	1	0
15	B1	927	1	0	0	0
		911	0	1	0	0
		912	0	0	0	1
		921	0	0	1	0
		922	0	0	0	1
		923	1	1	0	0
		924	0	0	0	1
		925	1	0	1	0
20	B2	926	0	1	0	0
		927	0	0	0	1
		911	0	0	0	1
		912	0	1	0	0
		921	1	0	0	0
		922	0	1	0	0
		923	0	0	1	1
		924	0	1	0	0
25	B2	925	1	0	1	0
		926	0	0	0	1
		927	0	1	0	0
		911	0	0	0	1
		912	0	1	0	0
		921	1	0	0	0
		922	0	1	0	0
		923	0	0	1	1
30	B2	924	0	1	0	0
		925	1	0	1	0
		926	0	0	0	1
		927	0	1	0	0
		911	0	0	0	1
		912	0	1	0	0
		921	1	0	0	0
		922	0	1	0	0
35	B2	923	0	0	1	1
		924	0	1	0	0
		925	1	0	1	0
		926	0	0	0	1
		927	0	1	0	0
		911	0	0	0	1
		912	0	1	0	0
		921	1	0	0	0

[0089] In the first phase of the power generation cycle of the first set A of adsorption vessels 210-A1, 210-A2, as illustrated in Figure 4, the first adsorption vessel 210-A1 of the first set A, i.e. the charged adsorption vessel 210 of the first set A in this phase, is coupled to the first end 501 of the power generation circuit 500 and the second adsorption vessel 210-A2 of the first set A, i.e. the discharged adsorption vessel 210 of the first set A in this phase, is coupled to the second end 502 of the power generation circuit 500, as indicated in the first row of Table 2. To couple the first adsorption vessel 210-A1 of the first set A to the first end 501 of the power generation circuit 500 the adsorbate outlet valve 911 at the first adsorption vessel 210-A1 of the first set A is opened, and the adsorbate outlet valves 911 at the other adsorption vessels 210-A2, 210-B1, 210-B2 of the system 100 are closed, as can be seen in the first column of Table 3. To couple the second adsorption vessel 210-A2 of the first set A to the second end 502 of the power generation circuit 500 the adsorbate inlet valve 912 at the second adsorption vessel 210-A2 of the first set A is opened, and the adsorbate inlet valves 912 at the other adsorption vessels 210-A1, 210-B1, 210-B2 of the system 100 are closed.

[0090] The first adsorption vessel 210-A1 of the first set A is also coupled primary to the heating circuit 300. Therefore, the second heating circuit valve 926 at the first adsorption vessel 210-A1 of the first set A is opened for coupling the first adsorption vessel 210-A1 of the first set A to the incoming portion of the heating circuit 300, and the first interconnection valve 923 at the first adsorption vessel 210-A1 of the first set A is opened for coupling the first adsorption vessel 210-A1 of the first set A to the next downstream adsorption vessel 210 in the heating circuit 300, which is the first adsorption vessel 210-B1 of the second set B coupled to the first heat recovery section 310 of the heating circuit 300 in this phase. The remaining valves 921, 922, 924, 925, 927 at the first adsorption vessel 210-A1 of the first set A are closed.

[0091] The second adsorption vessel 210-A2 of the first set A is also coupled to the cooling circuit 400. Therefore, the first cooling circuit valve 922 at the second adsorption vessel 210-A2 of the first set A is opened for coupling the second adsorption vessel 210-A2 of the first set A to the incoming portion of the cooling circuit 400, the second cooling circuit valve

927 at the second adsorption vessel 210-A2 of the first set A is opened for coupling the second adsorption vessel 210-A2 of the first set A to the return portion of the cooling circuit 400, and the bypass valve 924 at the second adsorption vessel 210-A2 of the first set A is opened for bypassing the second adsorption vessel 210-A2 of the first set A in the heating circuit 300. The remaining valves 921, 923, 925, 926 at the second adsorption vessel 210-A2 of the first set A are closed.

[0092] The first adsorption vessel 210-B1 of the second set B, i.e. the charged adsorption vessel 210 of the second set B in this phase, is coupled to the first heat recovery section 310 of the heating circuit 300. Therefore, the second interconnection valve 925 at the first adsorption vessel 210-B1 of the second set B is opened for coupling the first adsorption vessel 210-B1 of the second set B to the previous upstream adsorption vessel 210 in the heating circuit 300, which is the first adsorption vessel 210-A1 of the first set A coupled primary to the heating circuit 300 in this phase, and the first interconnection valve 923 at the first adsorption vessel 210-B1 of the second set B is opened for coupling the first adsorption vessel 210-B1 of the second set B to the next downstream adsorption vessel 210 in the heating circuit 300, which is the second adsorption vessel 210-B2 of the second set B coupled to the second heat recovery section 320 of the heating circuit 300 in this phase. The remaining valves 921, 922, 924, 926, 927 at the first adsorption vessel 210-B1 of the second set B are closed.

[0093] The second adsorption vessel 210-B2 of the second set B, i.e. the discharged adsorption vessel 210 of the second set B in this phase, is coupled to the second heat recovery section 320 of the heating circuit 300. Therefore, the second interconnection valve 925 at the second adsorption vessel 210-B2 of the second set B is opened for coupling the second adsorption vessel 210-B2 of the second set B to the previous upstream adsorption vessel 210 in the heating circuit 300, which is the first adsorption vessel 210-B1 of the second set B coupled to the first heat recovery section 310 of the heating circuit 300 in this phase, and the first heating circuit valve 921 at the second adsorption vessel 210-B2 of the second set B is opened for coupling the second adsorption vessel 210-B2 of the second set B to the return portion of the heating circuit 300. The remaining valves 922, 923, 924, 926, 927 at the second adsorption vessel 210-B2 of the second set B are closed.

[0094] Next, the first phase of the power generation cycle of the second set B is started, as illustrated in Figure 5 and indicated in the second row of Table 2. Hereby, by setting the valves 911-912, 921-927 at each of the adsorption vessels 210-A1, 210-A2, 210-B1, 210-B2 to the states indicated in the second column of Table 3, the first adsorption vessel 210-B1 of the second set B is coupled to the first end 501 of the power generation circuit 500 and primary to the heating circuit 300, the second adsorption vessel 210-B2 of the second set B is coupled to the second end 502 of the power generation circuit 500 and to the cooling circuit 400, the second adsorption vessel 210-A2 of the first set A is coupled to the first heat recovery section 310 of the heating circuit 300, and the first adsorption vessel 210-A1 of the first set A is coupled to the second heat recovery section 320 of the heating circuit 300.

[0095] Next, the second phase of the power generation cycle of the first set A is started, as illustrated in Figure 6 and indicated in the third row of Table 2. Hereby, by setting the valves 911-912, 921-927 at each of the adsorption vessels 210-A1, 210-A2, 210-B1, 210-B2 to the states indicated in the third column of Table 3, the second adsorption vessel 210-A2 of the first set A is coupled to the first end 501 of the power generation circuit 500 and primary to the heating circuit 300, the first adsorption vessel 210-A1 of the first set A is coupled to the second end 502 of the power generation circuit 500 and to the cooling circuit 400, the second adsorption vessel 210-B2 of the second set B is coupled to the first heat recovery section 310 of the heating circuit 300, and the first adsorption vessel 210-B1 of the second set B is coupled to the second heat recovery section 320 of the heating circuit 300.

[0096] Next, the second phase of the power generation cycle of the second set B is started, as illustrated in Figure 7 and indicated in the fourth row of Table 2. Hereby, by setting the valves 911-912, 921-927 at each of the adsorption vessels 210-A1, 210-A2, 210-B1, 210-B2 to the states indicated in the fourth column of Table 3, the second adsorption vessel 210-B2 of the second set B is coupled to the first end 501 of the power generation circuit 500 and primary to the heating circuit 300, the first adsorption vessel 210-B1 of the second set B is coupled to the second end 502 of the power generation circuit 500 and to the cooling circuit 400, the first adsorption vessel 210-A1 of the first set A is coupled to the first heat recovery section 310 of the heating circuit 300, and the second adsorption vessel 210-A2 of the first set A is coupled to the second heat recovery section 320 of the heating circuit 300.

[0097] At this stage, the power generation process has cycled through all phases of the power generation cycles of all the sets A-B of adsorption vessels 210, and is repeated by again starting the first phase of the power generation cycle of the first set A of adsorption vessels 210, as illustrated in Figure 4, and indicated in the first row of Table 2 and the first column of Table 3.

Claims

1. A system (100) for generating power from a heat source (1000), wherein the system (100) comprises:

at least one set (A-D) of a first adsorption vessel (210) and a second adsorption vessel (210), wherein each

adsorption vessel (210) comprises an adsorbent bed (220);
 an adsorbate suitable for being adsorbed on and desorbed from the adsorbent bed (220) of each adsorption vessel (210), wherein the adsorbate is adsorbed substantially on the adsorbent bed (220) of one adsorption vessel (210) of each set (A-D), wherein said one adsorption vessel (210) of each set (A-D) is referred to as a charged adsorption vessel (210), and wherein the other adsorption vessel (210) of each set (A-D) is referred to as a discharged adsorption vessel (210);
 a heating circuit (300) that is configured for being selectively coupled to the charged adsorption vessel (210) of any one of the at least one set (A-D), wherein the heating circuit (300) is configured for circulating a first heat exchange medium through a coupled adsorption vessel (210), wherein the heating circuit (300) is configured for being coupled to the heat source (1000) for heating the first heat exchange medium entering the coupled adsorption vessel (210) in order to heat the coupled adsorption vessel (210) for desorbing the adsorbate from the adsorbent bed (220) of the coupled adsorption vessel (210);
 a cooling circuit (400) that is configured for being selectively coupled to the discharged adsorption vessel (210) of the same set as the charged adsorption vessel (210) selectively coupled to the heating circuit (300), wherein the cooling circuit (400) is configured for circulating a second heat exchange medium through a coupled adsorption vessel (210), wherein the cooling circuit (400) is coupled to a cooling device (410) of the system (100) configured for actively cooling the second heat exchange medium entering the coupled adsorption vessel (210) in order to cool the coupled adsorption vessel (210) for adsorbing adsorbate received in the coupled adsorption vessel (210) on the adsorbent bed (220) of the coupled adsorption vessel (210); and
 a power generation circuit (500) that is configured for being selectively coupled at a first end (501) to the adsorption vessel (210) coupled to the heating circuit (300) and at a second end (502) to the adsorption vessel (210) coupled to the cooling circuit (400), wherein the power generation circuit (500) is configured for passing the adsorbate from the adsorption vessel (210) coupled to the heating circuit (300) to the adsorption vessel (210) coupled to the cooling circuit (400), wherein the power generation circuit (500) comprises a power generation device (510), such that power is generated when the adsorbate passes from the adsorption vessel (210) coupled to the heating circuit (300) to the adsorption vessel (210) coupled to the cooling circuit (400) through the power generation device (510).

2. The system (100) according to claim 1, wherein the cooling device (410) is configured for actively cooling the second heat exchange medium to a predetermined temperature.
3. The system according to claim 1 or 2, wherein the cooling device (410) is also coupled to the heating circuit (300) for heating with heat extracted from the second heat exchange medium the first heat exchange medium entering the adsorption vessel (210) coupled to the heating circuit (300).
4. The system (100) according to any one of the claims 1-3, wherein the system (100) further comprises:

at least two of the sets (A-D) of adsorption vessels (210);
 a first heat recovery section (310) in the heating circuit (300) downstream of the adsorption vessel (210) coupled to the heating circuit (300), wherein the first heat recovery section (310) is configured for selectively coupling in series to the charged adsorption vessel (210) of each of the at least one set (A-D) not coupled to the heating circuit (300) and the cooling circuit (400), wherein the heating circuit (300) is configured for circulating the first heat exchange medium through the at least one coupled adsorption vessel (210) of the first heat recovery section (310) after the first heat exchange medium has passed through the adsorption vessel (210) coupled to the heating circuit (300), thereby pre-heating the at least one coupled adsorption vessel (210) of the first heat recovery section (310) with residual heat in the first heat exchange medium and consequently cooling the first heat exchange medium by giving off the residual heat to the at least one coupled adsorption vessel (210) of the first heat recovery section (310);
 a second heat recovery section (320) in the heating circuit (300) downstream of the first heat recovery section (310), wherein the second heat recovery section (320) is configured for selectively coupling in series the discharged adsorption vessel (210) of each of the at least one set (A-D) not coupled to the heating circuit (300) and the cooling circuit (400), wherein the heating circuit (300) is configured for circulating the first heat exchange medium through the at least one coupled adsorption vessel (210) of the second heat recovery section (320) after the first heat exchange medium has passed through the at least one coupled adsorption vessel (210) of the first heat recovery section (310), thereby pre-cooling the at least one coupled adsorption vessel (210) of the second heat recovery section (320) by the at least one coupled adsorption vessel (210) of the second heat recovery section (320) giving off residual heat to the first heat exchange medium and consequently heating the first heat exchange medium with the residual heat of the at least one coupled adsorption vessel (210) of the

second heat recovery section (320).

5 5. The system (100) according to any one of the claims 1-4, wherein the power generation device (510) comprises an expansion turbine (512) coupled to a generator (514), such that when the adsorbate passes from the adsorption vessel (210) coupled to the heating circuit (300) to the adsorption vessel (210) coupled to the cooling circuit (400) through the expansion turbine (512) work is generated for driving the generator (514) to generate power.

6. The system (100) according to any one of the claims 1-5, wherein the cooling device (410) comprises:

10 a reservoir (820) for the second heat exchange medium in the cooling circuit (400) upstream of the coupled adsorption vessel (210); and
a vapour recompression device (412) configured for extracting and compressing vapour of the second heat exchange medium in the reservoir (820) for cooling the second heat exchange medium in the reservoir (820).

15 7. The system (100) according to any one of the claims 1-6, wherein the system (100) comprises a first heat exchanger (610) coupling the heating circuit (300) to the heat source (1000) for heating the first heat exchange medium entering the adsorption vessel (210) coupled to the heating circuit (300).

20 8. The system (100) according to any one of the claims 1-7, at least in combination with claim 3, wherein the system (100) comprises a second heat exchanger (620) coupling the cooling device (410) to the heating circuit (300) for heating with heat extracted from the second heat exchange medium the first heat exchange medium entering the adsorption vessel (210) coupled to the heating circuit (300).

25 9. A method for operating the system (100) according to any one of the claims 1-8, wherein in a first phase of a power generation cycle of a first set (A-D) of the at least one set (A-D) of adsorption vessels (210), in which the adsorbate is adsorbed substantially on the adsorbent bed (220) of the first adsorption vessel (210) of the first set (A-D), the method comprises the steps of:

30 coupling a heat source (1000) to the heating circuit (300);
coupling the first adsorption vessel (210) and the second adsorption vessel (210) of the first set (A-D) to respectively the first end (501) and the second end (502) of the power generation circuit (500);
coupling the first adsorption vessel (210) and the second adsorption vessel (210) of the first set (A-D) to respectively the heating circuit (300) and the cooling circuit (400);
35 heating the first adsorption vessel (210) of the first set (A-D) by circulating the first heat exchange medium in the heating circuit (300) through the first adsorption vessel (210) of the first set (A-D) for desorbing the adsorbate from the adsorbent bed (220) of the first adsorption vessel (210) of the first set (A-D);
passing the desorbed adsorbate through the power generation circuit (500) from the first adsorption vessel (210) of the first set (A-D) to the second adsorption vessel (210) of the first set (A-D) through the power generation device (510) for generating power; and
40 cooling the second adsorption vessel (210) of the first set (A-D) by circulating the second heat exchange medium in the cooling circuit (400) through the second adsorption vessel (210) of the first set (A-D) for adsorbing the adsorbate on the adsorbent bed (220) of the second adsorption vessel (210) of the first set (A-D).

45 10. The method according to claim 9, wherein in a second phase of the power generation cycle of the first set (A-D), after the adsorbate has been adsorbed substantially on the adsorbent bed (220) of the second adsorption vessel (210) of the first set (A-D), the method comprises the steps of:

50 coupling the first adsorption vessel (210) and the second adsorption vessel (210) of the first set (A-D) to respectively the second end (502) and the first end (501) of the power generation circuit (500);
coupling the first adsorption vessel (210) and the second adsorption vessel (210) of the first set (A-D) to respectively the cooling circuit (400) and the heating circuit (300);
heating the second adsorption vessel (210) of the first set (A-D) by circulating the first heat exchange medium in the heating circuit (300) through the second adsorption vessel (210) of the first set (A-D) for desorbing the adsorbate from the adsorbent bed (220) of the second adsorption vessel (210) of the first set (A-D);
55 passing the desorbed adsorbate through the power generation circuit (500) from the second adsorption vessel (210) of the first set (A-D) to the first adsorption vessel (210) of the first set (A-D) through the power generation device (510) for generating power; and
cooling the first adsorption vessel (210) of the first set (A-D) by circulating the second heat exchange medium in

the cooling circuit (400) through the first adsorption vessel (210) for adsorbing the adsorbate on the adsorbent bed (220) of the first adsorption vessel (210) of the first set (A-D).

- 5 11. The method according to claim 9 or 10, at least in combination with claim 4, wherein in the first phase of the power generation cycle of the first set (A-D), in which the adsorbate is also adsorbed substantially on the adsorbent bed (220) of the first adsorption vessel (210) of the at least one further set (A-D), the method also comprises the steps of:

10 coupling the first adsorption vessel (210) and the second adsorption vessel (210) of each of the at least one further set (A-D) to respectively the first heat recovery section (310) and the second heat recovery section (320), wherein the first adsorption vessel (210) and the second adsorption vessel (210) of a corresponding further set (A-D) are coupled at corresponding downstream positions to respectively the first heat recovery section (310) and the second heat recovery section (320);

15 pre-heating the first adsorption vessel (210) of each set (A-D) in the first heat recovery section (310) by circulating the first heat exchange medium in the heating circuit (300) through the first adsorption vessel (210) of each set (A-D) in the first heat recovery section (310) after the first heat exchange medium has passed through the first adsorption vessel (210) of the first set (A-D) coupled to the heating circuit (300), thereby cooling the first heat exchange medium; and

20 pre-cooling the second adsorption vessel (210) of each set (A-D) in the second heat recovery section (320) by circulating the first heat exchange medium in the heating circuit (300) through the second adsorption vessel (210) of each set (A-D) in the second heat recovery section (320) after the first heat exchange medium has passed through the first adsorption vessel (210) of each set (A-D) in the first heat recovery section (310), thereby heating the first heat exchange medium.

- 25 12. The method according to claim 11, wherein the method comprises after the first phase of the power generation cycle of the first set (A-D) a first phase of a power generation cycle of a second set (A-D) of the least two sets (A-D) of adsorption vessels (210), in which the second set (A-D) is the set (A-D) of adsorption vessels (210) at the first downstream position in the first heat recovery section (310) and the second heat recovery section (320), wherein the first phase of the power generation cycle of the second set (A-D) comprises the steps of:

30 decoupling the first adsorption vessel (210) and the second adsorption vessel (210) of the first set (A-D) from the power generation circuit (500);

decoupling the first adsorption vessel (210) and the second adsorption vessel (210) of the first set (A-D) from respectively the heating circuit (300) and the cooling circuit (400);

35 decoupling the first adsorption vessel (210) and the second adsorption vessel (210) of the second set from respectively the first heat recovery section (310) and the second heat recovery section (320);

coupling the first adsorption vessel (210) and the second adsorption vessel (210) of the second set (A-D) to respectively the first end (501) and the second end (502) of the power generation circuit (500);

coupling the first adsorption vessel (210) and the second adsorption vessel (210) of the second set (A-D) to respectively the heating circuit (300) and the cooling circuit (400);

40 coupling the first adsorption vessel (210) and the second adsorption vessel (210) of the first set (A-D) to respectively the first heat recovery section (310) and the second heat recovery section (320) at the last downstream position;

45 heating the first adsorption vessel (210) of the second set (A-D) by circulating the first heat exchange medium in the heating circuit (300) through the first adsorption vessel (210) of the second set (A-D) for desorbing the adsorbate from the adsorbent bed (220) of the first adsorption vessel (210) of the second set (A-D);

passing the desorbed adsorbate through the power generation circuit (500) from the first adsorption vessel (210) of the second set (A-D) to the second adsorption vessel (210) of the second set (A-D) through the power generation device (510) for generating power;

50 cooling the second adsorption vessel (210) of the second set (A-D) by circulating the second heat exchange medium in the cooling circuit (400) through the second adsorption vessel (210) of the second set (A-D) for adsorbing the adsorbate on the adsorbent bed (220) of the second adsorption vessel (210) of the second set (A-D);

55 pre-heating the first adsorption vessel (210) of each set (A-D) in the first heat recovery section (310) by circulating the first heat exchange medium in the heating circuit (300) through the first adsorption vessel (210) of each set (A-D) in the first heat recovery section (310) after the first heat exchange medium has passed through the first adsorption vessel (210) of the second set (A-D) coupled to the heating circuit (300), thereby cooling the first heat exchange medium; and

pre-cooling the second adsorption vessel (210) of each set (A-D) in the second heat recovery section (320) by

circulating the first heat exchange medium in the heating circuit (300) through the second adsorption vessel (210) of each set (A-D) in the second heat recovery section (320) after the first heat exchange medium has passed through the first adsorption vessel (210) of each set (A-D) in the first heat recovery section (310), thereby heating the first heat exchange medium.

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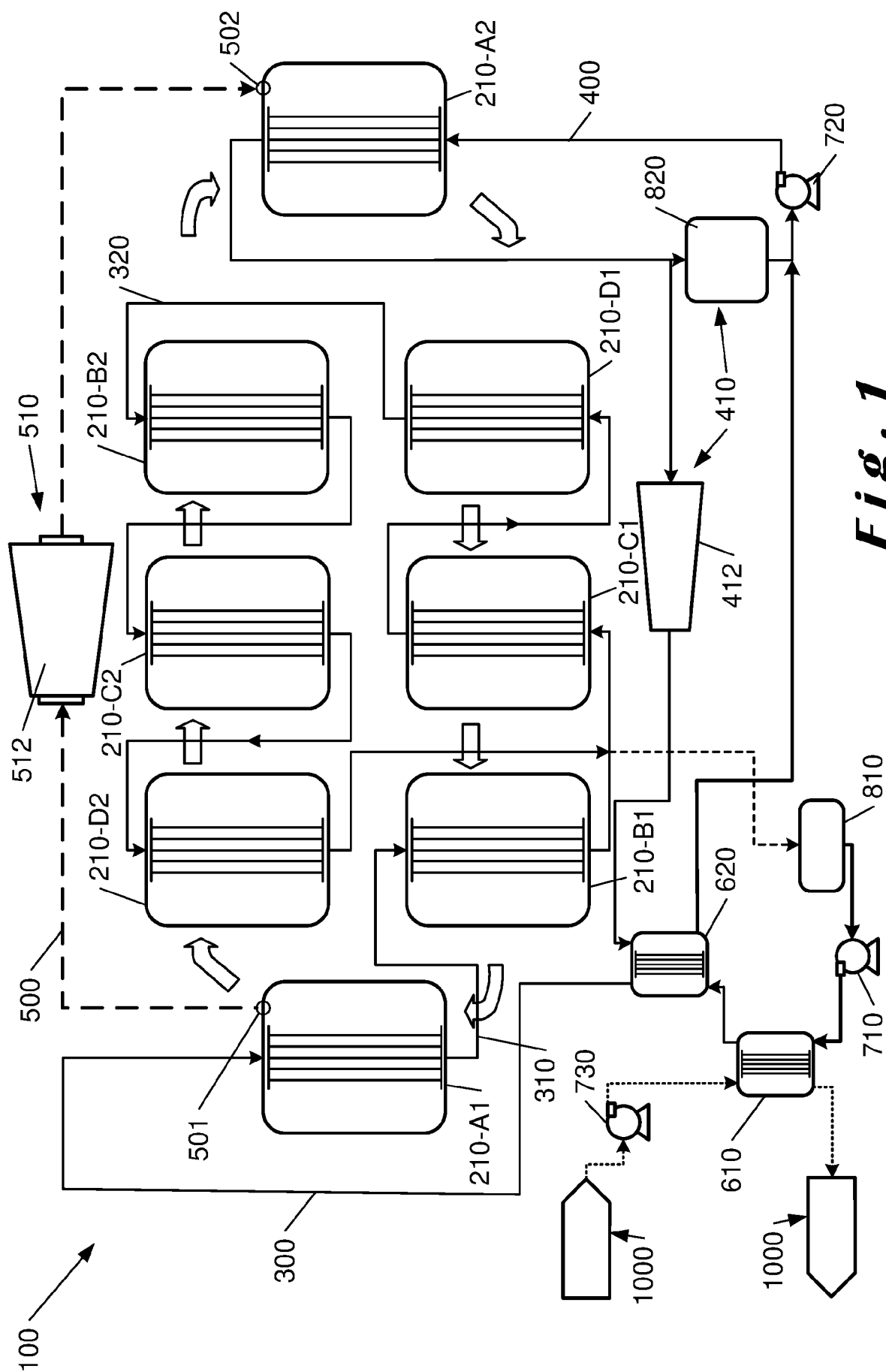
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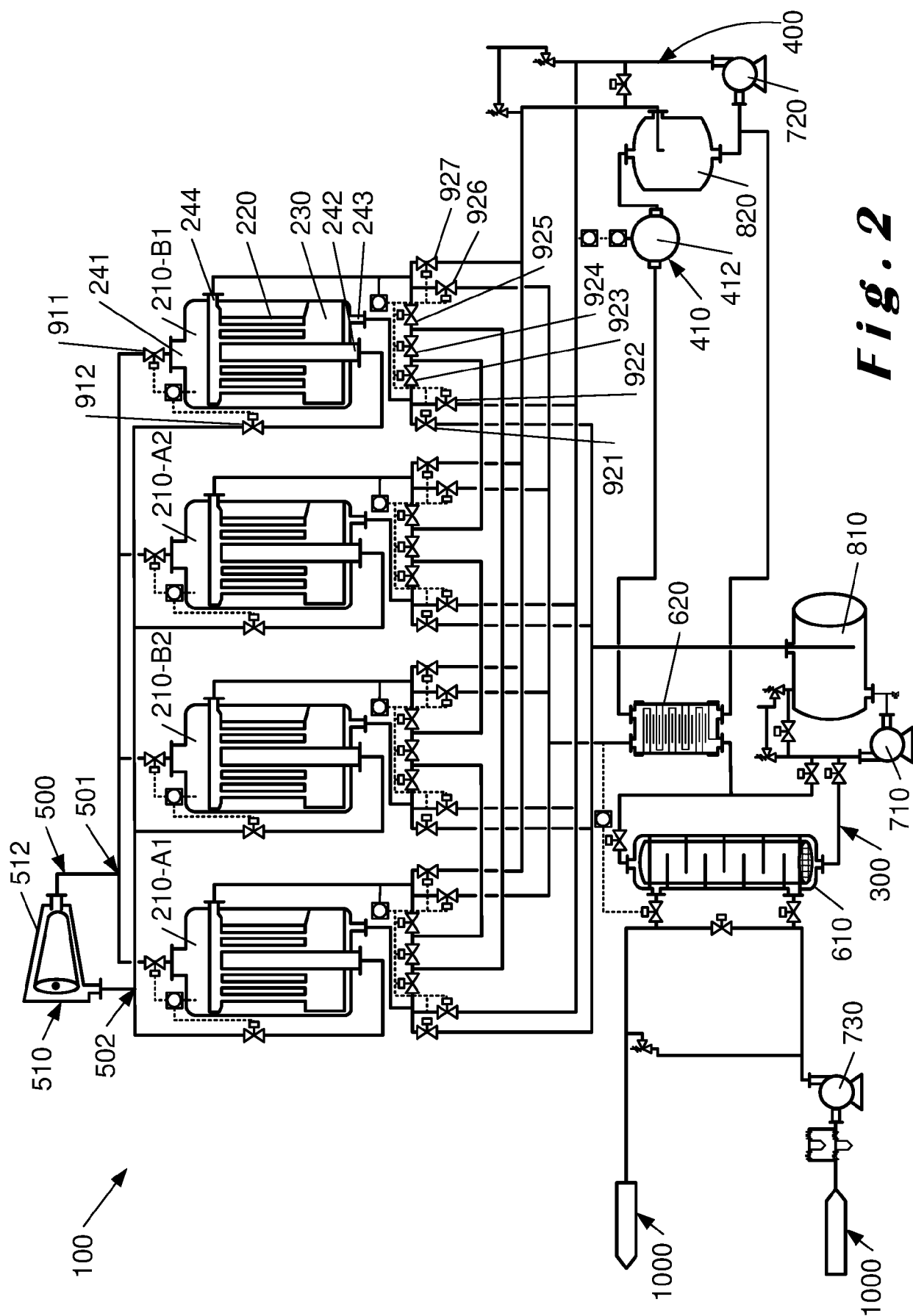


Fig. 2

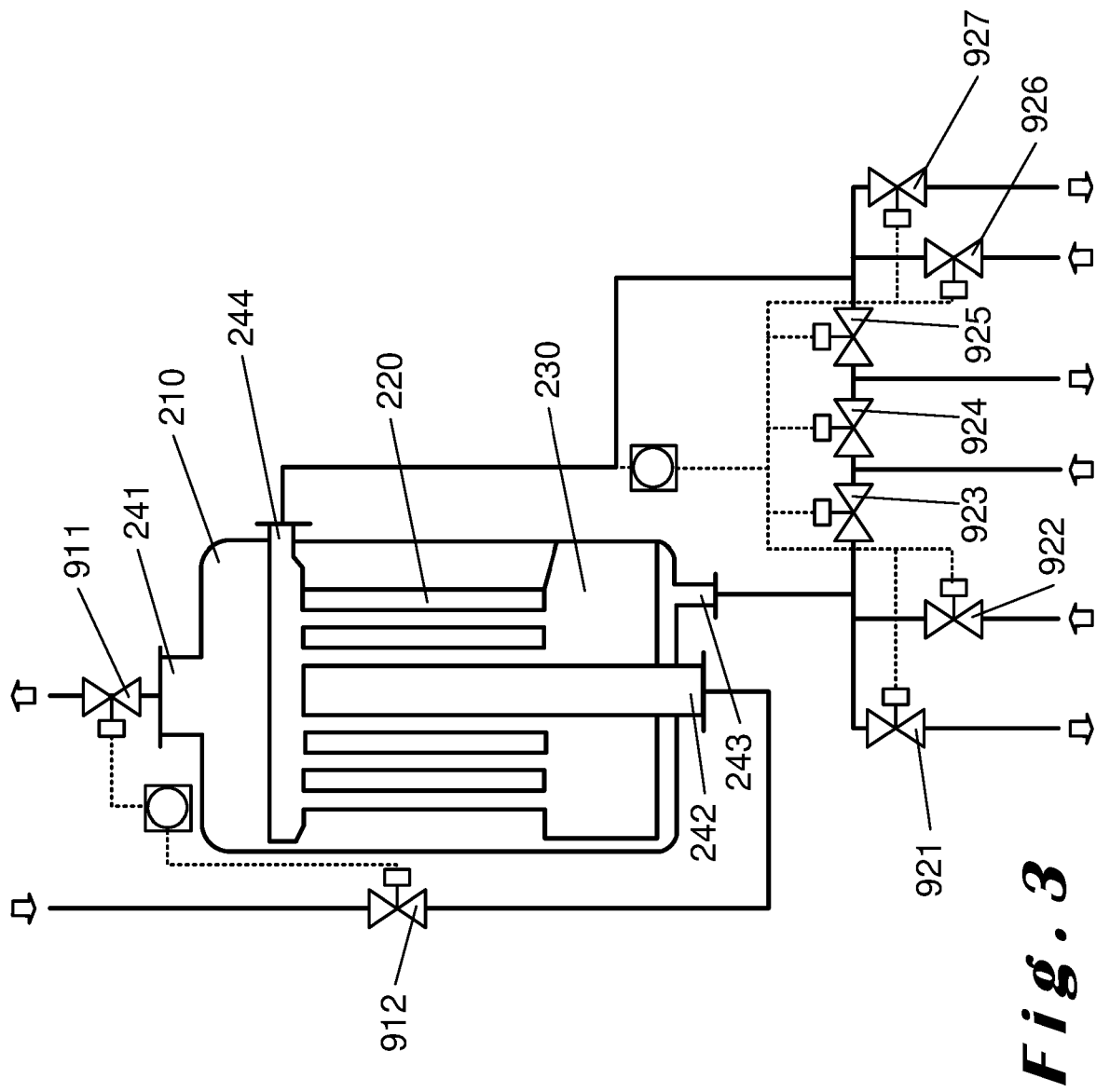
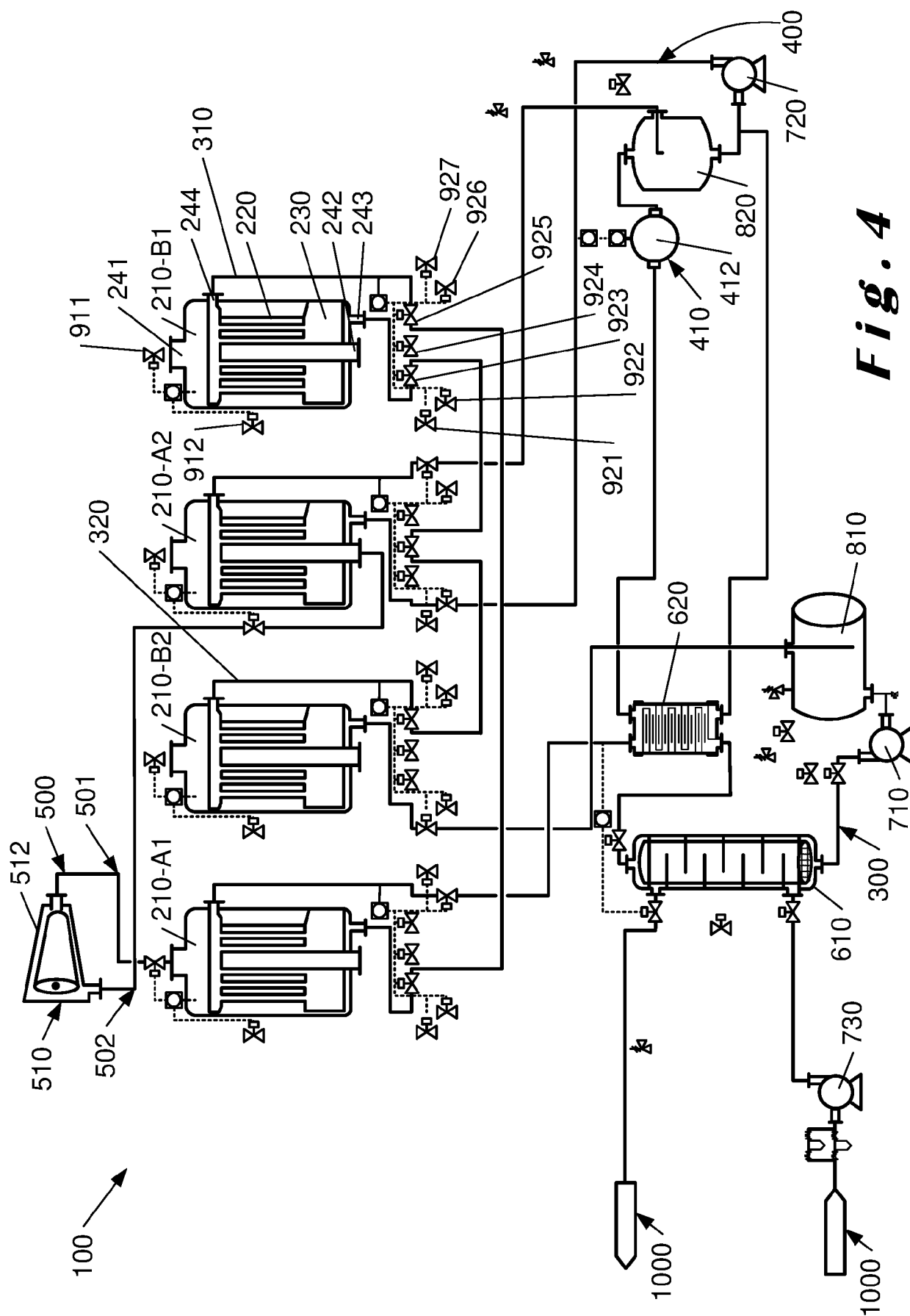
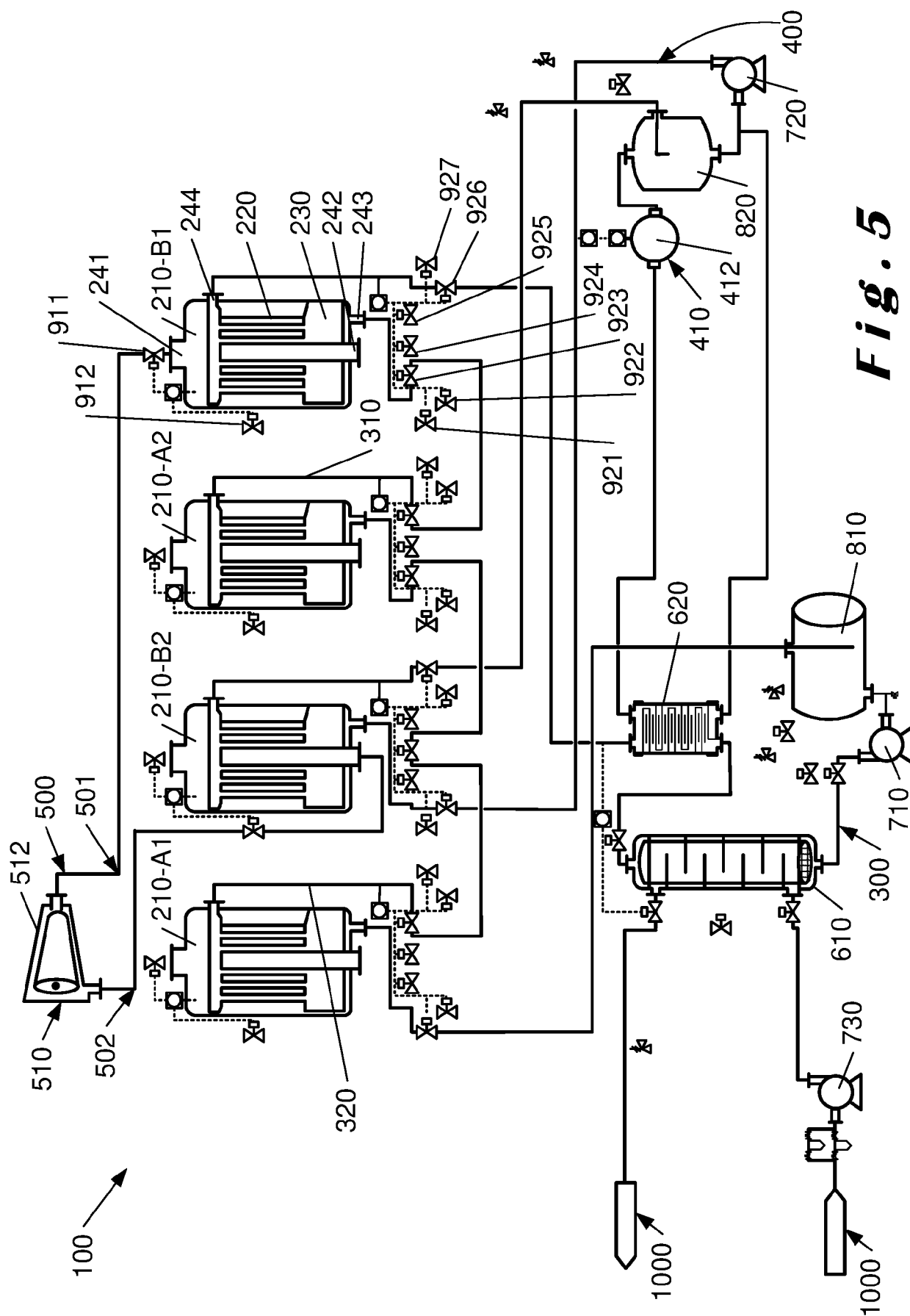


Fig. 3

**Fig. 4**

**Fig. 5**

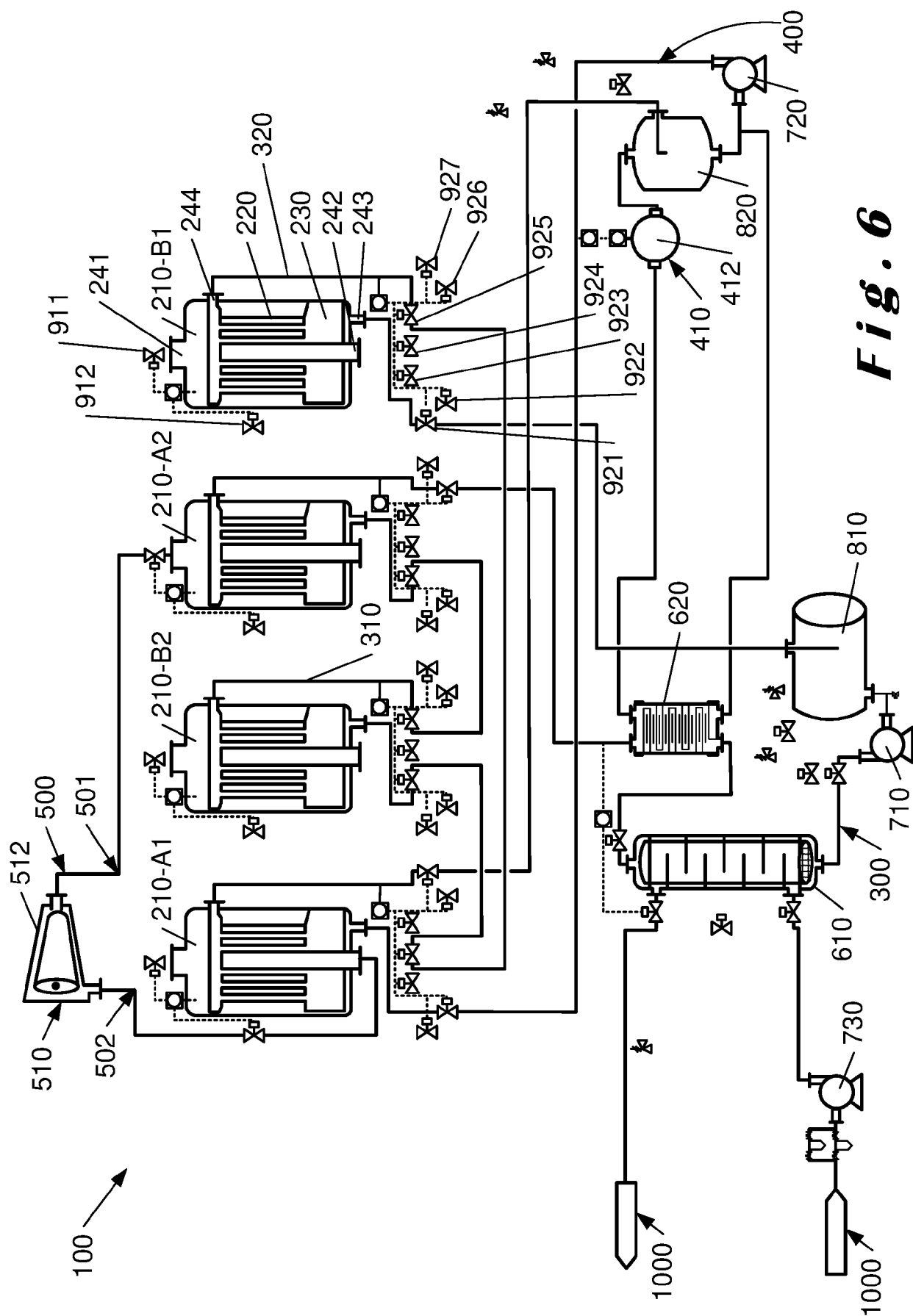
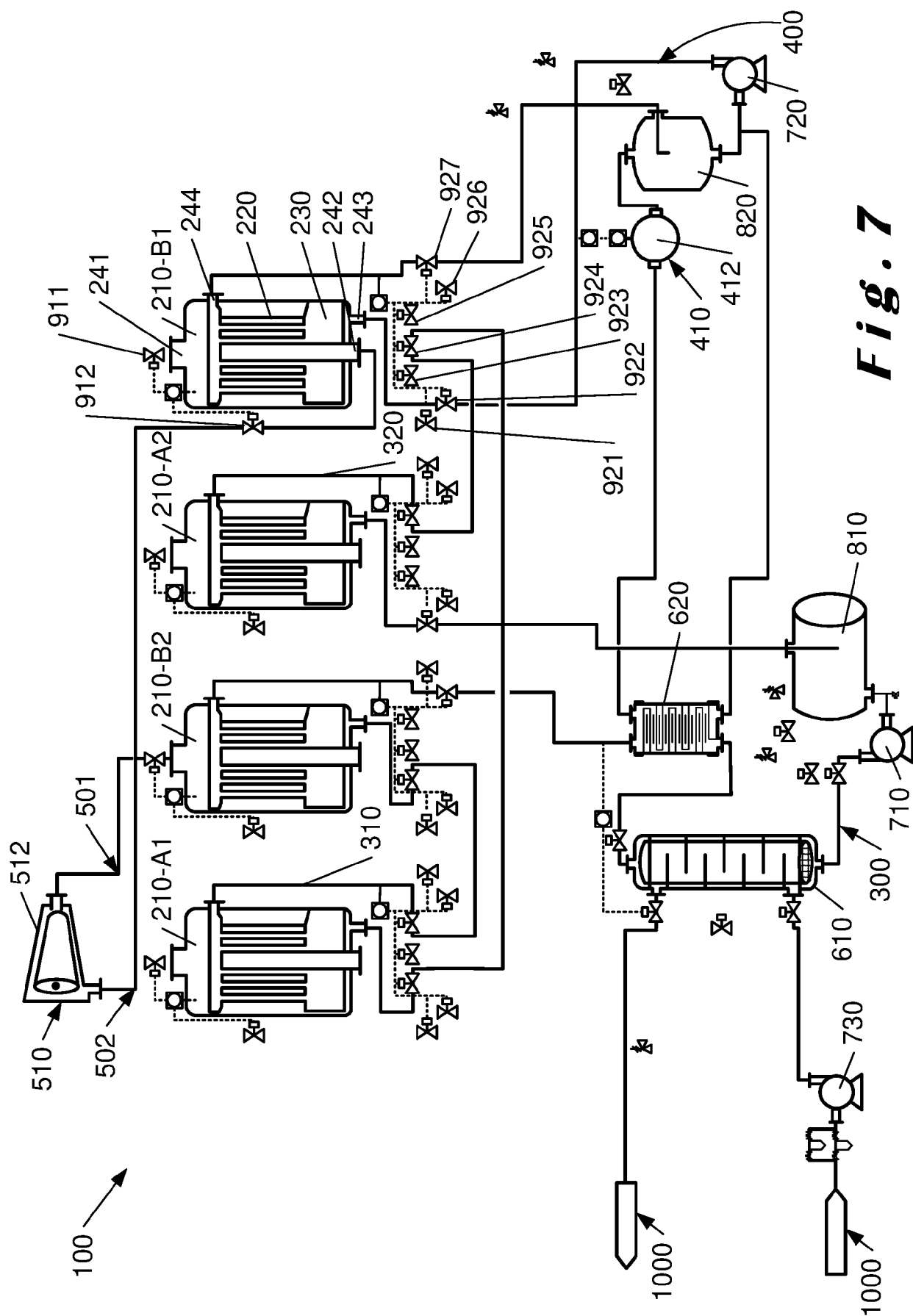


Fig. 6

**Fig. 7**



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Application Number

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