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(54) **PRESSURIZED CONTAINER FOR LIQUEFIED GAS AND CONSUMER CONNECTION**

DRUCKBEHÄLTER FÜR FLÜSSIGGAS UND VERBRAUCHERANSCHLUSS

RÉCIPIENT SOUS PRESSION POUR GAZ LIQUÉFIÉ ET RACCORD DE CONSOMMATEUR

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Description

BACKGROUND

[0001] Some gaseous materials can be advantageously liquefied at low temperatures in order to occupy less volume for better storage or transportation. Such liquefied gas may be either transferred to be consumed, or pressurized and then turned from a liquid phase back to a gaseous phase to be consumed. Such regasification process volume is, for example, occurring in industrial ports, where liquefied natural gas (LNG) is turned into compressed natural gas (CNG). Such regasification process consumes a significant amount of energy. Such energy is for example used to heat liquefied gas in order to evaporate it, as well as to run high power industrial pumps to transfer the gas through the regasification installation. The document WO2011059344 A1 discloses a method for the regasification of liquefied gases as LNG.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] Various example features will be apparent from the detailed description which follows, taken in conjunction with the accompanying drawings, wherein:

Figure 1 is a schematic representation of an example system according to the present disclosure.

Figures 2a-f are schematic representations of the example system of Figure 1.

Figure 3 is a schematic representation of another example system according to the present disclosure.

Figure 4 is a schematic representation of a further example system according to the present disclosure.

Figures 5a-e are schematic representations of the example system of Figure 4.

Figure 6 is a schematic representation of a further example system according to the present disclosure.

Figure 7 is a schematic representation of a further example system according to the present disclosure.

Figure 8 is a block diagram representation of an example regasification method according to the present disclosure.

Figure 9 is a block diagram representation of an example method to cyclically modify pressure according to the present disclosure.

Figure 10 is a schematic representation of an example system according to the present disclosure.

Figure 11 is a schematic representation of an example system according to the present disclosure.

DETAILED DESCRIPTION

[0003] The present disclosure aims at reducing or even at suppressing the energy costs of pumping a fluid into a regasification or transfer installation to produce a high pressure gas or pressurized liquefied gas downstream. In that case, while ambient temperature may be used to evaporate a liquefied gas if the liquefied gas temperature is lower than ambient, prior art systems are using high power pumps to evacuate the liquid fluid. The present disclosure not only permits using ambient temperature to pressurize liquefied gas, but also avoids the use of a pump through an elegant construction which will be described in more detail below. In particular, example systems allow producing a cycle between three equivalent containers and three types of fluids (compressed liquid or gas, liquefied gas, and gas at lower pressure than compressed gas) such that the energy stored in pressure and temperature of the fluids gets exchanged to move the fluid between containers and run the cycle with a minimal energy cost.

[0004] As illustrated in Figure 1, this disclosure relates to a system for providing a compressed gas or a compressed liquefied gas. In an example, compressed gas comprises a gaseous phase and also comprises some gas in a liquid phase. In an example, more than 70% of the compressed gas in mass is in a gaseous phase. In an example, less than 5% of the compressed gas in mass is in a liquid phase. In an example, the compressed gas is liquid in more than 99% of its mass. In an example, compressed gas is at a pressure of between 6 and 10 bar. In an example, compressed gas is at a pressure of between 25 and 35 bar. In an example, compressed gas is at a pressure of at least 200 bar. In an example, the compressed gas comprises natural gas. In an example, the compressed gas comprises air. In an example, the compressed gas comprises N₂. In an example, the compressed gas comprises O₂. In an example, the compressed gas is at a temperature of between -90 and -60 degrees Celsius. In an example, the compressed gas is at a temperature of between -60 and -25 degrees Celsius.

[0005] The system of Figure 1 according to this disclosure comprises a supply connection 300 for the supply of liquefied gas. In an example, the liquefied gas comprises a liquid phase and also comprises some gas in a gaseous phase. In an example, more than 70% of the liquefied gas in mass is in a liquid phase. In an example, less than 5% of the liquefied gas in mass is in a gaseous phase. In an example, the liquefied gas is in a liquid phase in more than 99% of its mass. In an example, liquefied gas is at a pressure of between 1 and 2 bar. In an example, compressed gas is at a pressure of between 2 and 4 bar. In an example, liquefied gas is at a pressure of at least 4 bar. In an example, the liquefied gas comprises natural gas. In an example, the liquefied gas comprises cryogenic liquid natural gas. In an example, the

liquefied gas comprises air. In an example, the liquefied gas comprises N₂. In an example, the liquefied gas comprises O₂. In an example, the liquefied gas is at a temperature of between -180 and -140 degrees Celsius. In an example, the liquefied gas is at a temperature of between -160 and -80 degrees Celsius.

[0006] The system of Figure 1 according to this disclosure comprises three pressurized containers 101, 102 and 103. In an example, the pressurized containers are pressure vessels designed to hold a fluid such as a gas, liquid or a combination of both at a pressure different from the ambient pressure. In an example, the pressurized containers are made of steel. In an example, the pressurized containers have a generally cylindrical enclosure. In an example, a pressurized container has an inner volume of at least 0.3 cubic meters. In an example, the three pressurized containers 101, 102 and 103 have an identical structure. In an example, the three pressurized containers 101, 102 and 103 are located at the same level, meaning at the same altitude, in order to minimize an impact of gravity on a method to cyclically modify pressure according to this disclosure.

[0007] The system of Figure 1 according to this disclosure comprises an evaporator 210. In an example the evaporator comprises radiating surfaces whereby liquefied gas passing through the evaporator is exposed to ambient temperature or is heated by a heating fluid through the radiating surfaces, thereby transmitting heat to the liquefied gas, raising its temperature and progressively reducing its liquid phase, increasing its gaseous phase, and increasing pressure inside the vessel or container as fluid passes through the evaporator. In an example, the evaporator is a passive radiator using ambient air as heat transfer fluid. In an example, the evaporator is a forced circulation evaporator, using forced circulation from a heat transfer fluid to evaporate the liquefied gas.

[0008] The system of Figure 1 according to this disclosure comprises a heat exchanger. The heat exchanger is a counter current flow heat exchanger having two inputs and two outputs; two inputs and a first output being connected to the pressurized containers 101, 102, 103, the second output being connected to a consumer connection 400. Using a counter flow heat exchanger contributes to obtaining the energy savings aimed at in the current disclosure by using the difference in temperature between the compressed gas and the liquefied gas in the system of the disclosure in a beneficial manner as will be explained below.

[0009] The system of Figure 1 according to this disclosure comprises a consumer connection 400. The consumer connection is in an example a connection to a compressed gas distribution network. In an example, the consumer connection connects to a network distributing compressed natural gas. The consumer connection 400 is connected to the heat exchanger. In the system of this disclosure, a connection between elements is a pressurized connection allowing a transfer of fluid (fluid including gas, liquid, or a mixture of gas and liquid) between an element and another element, the connection being direct or indirect. A direct connection can be provided by a tube between elements. A direct connection can be provided by a tube mechanically connected to elements with seals maintaining pressurization of the system. Elements include for example the supply connection, the pressurized containers, the evaporator, the heat exchanger, valves or an expansion element. An indirect connection can be provided between a first element and a second element if one or more further elements is or are placed between the first and the second element, meaning that a fluid moving between the first and the second element would pass through the one or more further elements when moving from the first to the second element or vice versa. In an example, the system comprises a pressurized circuit between the elements of the system.

[0010] The system of Figure 1 according to this disclosure comprises valves interconnecting each pressurized container 101, 102, 103 with the supply connection 300, with the evaporator 210, and with the heat exchanger. In this example, valves 701, 702, 703 control the connection of respective containers 101, 102, 103 with a first fluid connection of the evaporator 210 through an additional valve 710. Valves 707, 708 and 709 control the connection of respective containers 101, 102 and 103 with a second fluid connection of the evaporator 210. The evaporator 210 comprises an internal fluid circuit between its first fluid connection and second fluid connection. Valves 704, 705 and 706 control the connection of the respective containers 101, 102 and 103 through the respective valves 707, 708 and 709 to the input of the current flow channel 501 of the heat exchanger. Valve 714 controls the connection between the output of the current flow channel 501 of the heat exchanger to consumer connection 400. Valves 711, 712 and 713 control the connection of respective containers 101, 102 and 103 to the input of counter current flow channel 502 of the heat exchanger. Valve 700 controls the connection of supply connection 300 to the rest of the system. Valves 715, 716 and 717 control the connection of respective containers 101, 102 and 103 to the output of counter current flow channel 502 of the heat exchanger through an expansion element 600. As will be evidenced in this description, this is only an example of connection between elements of the circuit, and different circuits may be designed which will lead to a system according to this disclosure.

[0011] The system of Figure 1 according to this disclosure comprises an expansion element 600. In an example, an expansion element reduces temperature in a fluid which flows through the expansion element. In an example, a fluid entering the expansion element has a higher proportion of gaseous phase than the fluid exiting the expansion element, and the fluid entering the expansion element has a lower proportion of liquid phase than the fluid exiting the expansion element. In an example, the expansion element 600 comprises a Joule-Thomson valve or a throttling element. The expansion element 600 is located between the first output of the counter current flow heat exchanger and the pressurized containers. In an example, fluid flow through the expansion element goes from the output of the counter current flow

channel 502 towards one or more of containers 101, 102 or 103.

[0012] In Figure 2a, the system of Figure 1 is represented in a specific state. In Figure 2a, container 101 is filled with liquefied gas. Container 101 is filled by opening valves 701 and 700 between container 101 and supply connection 300 for the supply of liquefied gas. In our Figures, open valves are represented by two opposing white triangle, while closed valves are represented by two opposing black triangles. In Figure 2a, container 101 gets filled by liquefied gas because the valves 700 and 701 are open and because pressure in container 101 is lower than pressure in the supply connection 300. In an example, pressure in container 101 is of 6 bar and pressure in the supply connection 300 is 7 bar. In figure 2a, liquefied gas is supplied to a first pressurized container 101, the container being at a first pressure. In Figure 2a, container 102 is filled with gas in a gaseous phase at about 5 bar represented by a light gray texture, and container 103 is filled with compressed gas at about 200 bar, represented by a dark gray texture. Containers 102 and 103 are in Figure 2 closed and without fluid connection to other elements due to valves being closed.

[0013] In Figure 2b, the system of Figure 1 is represented in a state directly following the state represented in Figure 2a. In Figure 2b, valve 700 has been closed after the filling of container 101 by liquefied gas through the supply connection 300. In Figure 2b, both valves 710 and 707 have been opened, and valve 701 was maintained opened, so that a circuit is open between container 101 and evaporator 210. When the system is in this configuration, the first pressurized container 101 is connected to evaporator 210 to evaporate liquefied gas to produce a first fluid and increase pressure in the first pressurized container 101 to a second pressure. In an example, the pressure in the container 101 raises from about 5 bar to about 200 bar during this phase, whereby the liquefied gas progressively turns into compressed gas through evaporation. In Figure 2b, we have illustrated a gaseous phase in container 101, the gaseous phase being illustrated in a dark shade above the liquefied gas phase illustrated by horizontal dashed lines. The remaining valves in the system remain closed. During this phase, pressure raises in container 101 through evaporation in evaporator 210.

[0014] In Figure 2c, the system of Figure 1 is represented in a state directly following the state represented in Figure 2b. In Figure 2c, valves 701, 707 and 710 remain open as in Figure 2b, so that the liquefied gas continues to be submitted to evaporation. In figure 2c, valves 704 and 714 are open so that the fluid present in container 101 exits at the second pressure for example of the order of 200 bar through consumer connection 400. Indeed, the first container 101 is connected with consumer connection 400 via a channel 501 of a heat exchanger, the second pressure being higher than a pressure in the consumer connection 400. In parallel to the flow from both container 101 and evaporator 210 towards the consumer connection through current flow channel 501 of the heat exchanger, a counter current flow takes place in counter current flow channel 502. The counter current flow is produced by opening valves 713 and 716. Second pressurized container 103 containing a second fluid, in this example compressed gas at a pressure of about 200 bar in a gaseous phase, is connected to third pressurized container 102, in this example originally filled with gas at a pressure of about 5 bar in a gaseous phase, such connection being via counter current flow channel 502 of the heat exchanger, the second fluid reducing its temperature as it flows through the counter current flow channel, whereby in this example it exchanges heat with the fluid passing through channel 501, the pressure in the second container 103 being higher than the pressure in the third container 102, the second fluid passing through expansion element 600 between the counter flow exchanger and the third pressurized container 102.

[0015] In the example of Figure 2c, there is a first fluid circuit where a liquefied gas at high pressure and low temperature raises in pressure as it flows through the heat exchanger through channel 501. The resulting high pressure mixture of liquid and gas is aimed at being distributed to consumers through the connection. In parallel, another circuit through the counter current flow channel 502 and expansion element 600 turns high pressure compressed gas in gaseous phase into a gas at a much lower pressure and which may include a liquid phase. These two fluid circuits interact within the heat exchanger, whereby on of the fluids raises its temperature and the other lowers its temperature. The fluid flowing through the counter current flow channel 502 lowers its temperature, the fluid flowing through the current flow channel 501 raises its temperature. One should note that the terminology counter current flow channel and current flow channel is relative and that both channels are equivalent but are containing flows running in opposite directions.

[0016] In the example of Figure 2c, container 101 contains a fluid which has an increasing gaseous compressed phase, and a decreasing liquefied gas phase. In parallel, pressure in container 103 reduces, and the fluid contained in container 102 progressively contains a higher liquefied gas phase, due to the compressed gas of container 103 lowering its temperature in the heat exchanger and its pressure in the expansion element 600.

[0017] In Figure 2d, the system of Figure 1 is represented in a state directly following the state represented in Figure 2c. The valves in Figure 2d are in the same position as per Figure 2c. The change is illustrated by showing that container 101 has reached a stage at which it is filled with high pressure compressed gas, for example about 200 bar, resulting from raising the liquefied gas in both temperature and pressure. Container 102 now comprises a higher proportion of liquefied gas and remains at a relatively low pressure of the order of 5 bar. Container 103 is also at low pressure, for example containing gas at a pressure around 5 bar. The representation of the various phases of fluid on the Figures are symbolic in that some of the phases may intermix and have a variety of proportions.

[0018] In Figure 2e, the system of Figure 1 is represented in a state directly following the state represented in Figure 2d. All valves have now been closed except valves 700 and 702 in order to progressively fill container 102 with liquefied

gas, until it reaches a level of filling as illustrated in Figure 2f. The filling may be complete or may be partial. If one compares Figures 2f and 2a, one will see that the situations are equivalent, but that the containers have now exchanged roles. One can illustrate this change of roles in a cyclic manner in a table:

Figure	Content of Container 101	Content of Container 102	Content of Container 103	Comment
2a	Liquefied gas	Low pressure gas	Compressed gas	Start of cycle 1
2f	Compressed gas	Liquefied gas	Low pressure gas	End of cycle 1 and start of following cycle 2
Not illustrated	Low pressure gas	Compressed gas	Liquefied gas	End of cycle 2 and start of following cycle 3
2a	Liquefied gas	Low pressure gas	Compressed gas	End of cycle 3 and start of following cycle 4

[0019] As illustrated in the table, a cycle between containers allows providing compressed gas from liquefied gas to a supply network without the need of a pump. While low power fluid pumps may help run the cycle of this disclosure, in an example, the system is a pumpless system. The pressurized containers repeat the above steps using a circular permutation between the first, second and third containers, each container cycling through successive phases of being supplied with liquefied gas as per figure 2a for first pressurized container 101, evaporating liquefied gas as per figure 2b for first pressurized container 101, consumer connection as per figure 2c for first pressurized container 101 and depressurisation as per the transition between figures 2c and 2d for second pressurized container 103. Depressurization should be understood as a phase during which pressure decreases.

[0020] Numerous systems or circuits according to the disclosure may be designed. Another example is illustrated in Figure 3. The system of Figure 3 comprises the elements of the system of Figure 1 and further comprises a second evaporator 2002, the second evaporator being connected to each of the pressurized containers 101, 102 and 103. The system of Figure 3 permits an accelerated cycle. In an example both evaporators 210 and 220 are evaporating the fluid passing through them using ambient temperature. When using ambient temperature, some evaporators can become covered in ice considering the low temperature of liquefied gas, thereby reducing the evaporation process. For example, adding another evaporator helps compensating such a reduction, for example. One should note that the term evaporator in this disclosure can include a plurality of evaporators. Evaporator 220 in the system of Figure 3 is connected to its own valve 720 allowing to selectively control use of evaporator 220.

[0021] A further example of a system according to the disclosure is illustrated in Figure 4, whereby the system comprises a first evaporator 231, second evaporator 232 and third evaporator 233, being connected to each of the pressurized containers 101, 102 and 103, in this case respectively. Such plurality of evaporators can be considered thermodynamically as one evaporator. Such a design includes valves 731, 732 and 733, each corresponding to respective evaporators 231, 232 and 233. Such a design permits using less valves than the system of Figure 1. It is indeed possible to implement numerous various system according to this disclosure. The design of Figure 4 avoids using an evaporator 231, 232 or 233 continuously, whereby the evaporator would be connected to its respective container when such container is in a cycle of having its content passing from liquefied gas to compressed gas, such that the respective evaporator may not be used when the respective container is in a different part of the cycle, for example when its content changes from low pressure gas to compressed gas or when it is getting filled with liquefied gas. Such intermittent use of an evaporator can allow such evaporator to raise its temperature to prepare for a new cycle, for example if exposed to ambient conditions and submitted to freezing due to a low below freezing temperature of a liquefied gas.

[0022] The system of Figure 4 is illustrated when functioning in figures 5a to 5e. In Figure 5a, container 101 is filled with liquefied gas by opening valves 701 and 700, thereby connecting supply connection 300 with container 101. Container 102 is filled with gas in gaseous phase at low pressure, for example 5 bar and Container 103 by compressed gas at for example 200 bar. In Figure 5b, representing a state following in the cycle the state of Figure 5a, all valves are closed except valve 731, thereby starting evaporation of the content of container 101, raising pressure into container 101, reducing the liquid phase in container 101. The state of the system of Figure 4 illustrated in Figure 5b is followed by a state illustrated in Figure 5c, whereby the evaporator 231 continues to evaporate the content of container 101, whereby the higher pressure content of container 101 goes through open valves 704, through the current flow channel 501 of a heat exchanger, through open valve 714 and to a consumer connection, providing compressed gas at high pressure such as about 180000 hPa for example. In parallel, valves 702 and 713 are open to allow a fluid flow between container 103 and container 102, whereby the compressed gas of container 103 lowers its temperature while flowing through counter current flow channel 502 of the heat exchanger, lowering its pressure while flowing through expansion element

600, and enter container 102 with lower pressure and temperature, for example comprising a liquefied gas phase. Such flows of fluid illustrated in Figure 5c lead to a state illustrated in Figure 5d, the valves in 5d being in the same positions as in 5c, where the content of the containers is such that container 103 contains gas at a lower pressure and container 101 compressed gas at a higher pressure. 102 is at a lower pressure and lower temperature and may contain some liquefied gas. In Figure 5e, illustrating a state following the state of Figure 5d, all valves are closed except valves 700 and 702 allowing filling of container 102 with liquefied gas in order to start a new cycle, container 102 now playing the role played in the earlier cycle by container 101.

[0023] Another example of a system according to the invention is illustrated in Figure 6. The system illustrated in Figure 6 comprises the elements of the system illustrated in Figure 1, and the second output of the heat exchanger or the consumer connection is connected to the gas phase of the containers, at the evaporator 210 output, via a valve 740. Such connection permits injecting compressed gas into the containers, thereby raising the temperature and pressure in the evaporator, for example to permit resetting the circuit or system if the evaporator is saturated in its function and does not evaporate with a satisfactory yield. Such connection could be considered at other point of the circuit.

[0024] Another example of a system according to the invention is illustrated in Figure 7. In Figure 7, a system is illustrated which comprises the elements of the system illustrated in Figure 1 and further includes a supply tank 104 for the liquefied gas, the supply tank 104 being connected to the three pressurized containers 101, 102 and 103. Supply tank 104 may have been filled with liquefied gas coming from a liquefied gas transporting ship for example. One should note that in the system illustrated in Figure 7 the supply connection is a one way connection, meaning that there is no fluid flowing from the system back into the supply tank. Avoiding such a return of fluid through a one way connection avoids raising the temperature in the supply tank unnecessarily, and minimize cavitation risk. In the system illustrated in Figure 7, the system further includes an additional liquefied gas supply connection from the containers low output (low output meaning a container output at the bottom of the containers, the bottom being defined according to gravity) to an additional consumer connection 401 through a valve 750. Such additional consumer connection may be used to, for example, fill liquefied gas transportation means such as a tanker truck. Not only would a system as per this disclosure allow providing compressed gas from liquefied gas in a remote area or in an area which does not benefit from a high power electrical connection for a high power pump, but such an additional consumer connection would also allow providing liquefied gas directly.

[0025] Figure 8 illustrates a regasification or pressurizing method according to the disclosure. Such a method can be applied to any system according to the disclosure. In this example, we are describing it applied to the system illustrated in Figure 1. Regasification is the process of returning to a gaseous phase a gas which has been liquefied. The method illustrated in Figure 8 comprises in step 801 supplying liquefied gas to a first pressurized container such as 101, the pressurized container 101 being at a first pressure. Step 802 illustrates connecting the first pressurized container 101 to evaporator 210 to evaporate liquefied gas to produce a first fluid and increase pressure in the first pressurized container to a second pressure. Step 803 illustrates connecting the first pressurized container 101 with consumer connection 400 via a channel 501 of a heat exchanger, the first fluid raising its temperature as it flows through the channel 501, the second pressure being higher than a pressure in the consumer connection 400. Step 804 illustrates connecting a second pressurized container 103 containing a second fluid with a third pressurized container 102 via a counter current flow channel 502 of the heat exchanger, the second fluid reducing its temperature as it flows through the counter current flow channel 502, the pressure in the second pressurized container 103 being higher than the pressure in the third pressurized container 102, the second fluid passing through an expansion element 600 between the counter flow exchanger and the third pressurized container 102. In an example, the liquefied gas comprises cryogenic liquid natural gas and the first fluid comprises compressed natural gas.

[0026] Figure 9 illustrates a method to cyclically modify pressure in a pressurized container according to this disclosure. This method can be applied to any container described in the present disclosure. We illustrate it here using the system illustrated in Figure 1. The method consists in repeating the following steps in a cycle providing in step 901 a one way supply 300 of liquefied gas in the pressurized container 101, the pressurized container 101 being at a first pressure; evaporating in step 902 the liquefied gas provided in the first pressurized container 101, raising the pressure in the pressurized container 101 to a second pressure, the content of the first pressurized container 101 being evacuated from the pressurized container 101 towards a consumer connection 400 through a heat exchanger, the second pressure being higher than a consumer connection pressure; lower in step 903 the pressure in the pressurized container 101 to a third pressure by connecting the pressurized container 101 to an other pressurized container 103 through a counter current flow 502 of the heat exchanger and through an expansion element 600, the other pressurized container 103 containing a low pressure fluid, the low pressure fluid having a low pressure of less than the first pressure, the expansion element 600 being located between the heat exchanger and the other pressurized container 103. In this example, steps 901, 902 and 903 are repeated in cycle. In an example, the steps are implemented by opening and closing valves, the valves introducing losses of pressure. In another example, the steps are implemented by using a pump in addition to valves. In an example, the pressurized container 101 is filled with liquefied gas providing a one way supply of liquefied gas in the pressurized container 101, thereby avoiding returning fluid into a supply tank or supply network. In an example,

the first pressure is of less than 6 bar and the consumer connection pressure is of more than 200 bar.

[0027] Figure 10 is a schematic representation of a further example system according to the present disclosure. This example comprises the elements of Figure 1 as well as an additional inlet or additional supply connection 402 connected to an additional channel 503 of the heat exchanger through an additional valve 718. Such additional elements permit for example an additional supply of pressurized liquefied gas, compresses gas or mixture of these into the system in order to cool such additional supply. Such cooled additional supply is rerouted into the expansion element 600. The cooling of this additional supply takes place by flowing through additional channel 503 which is a counter current flow channel which participates to the heat exchange in a manner similar to counter current flow channel 502. A possible use of such additional supply would be for vehicles propelled exclusively or partially by liquefied or compressed gas as a fuel which should expel part of such fuel due for example to a high pressure in tanks containing such fuel. Such use would not only prevent releasing fuel into the atmosphere, but permit recycling such fuel using the system of this disclosure. While such additional supply is illustrated in the context of the system Figure 1, such additional supply may also be provided in the context of other system according to this disclosure. Such an additional supply may be controlled by a valve such as valve 718 which may open or close such an additional supply. When used, such additional supply would pass through expansion element 600 which turns high pressure compressed gas in gaseous phase into a gas at a much lower pressure and which may include a liquid phase. Such additional supply thereby participates to the method to cyclically modify pressure according to this disclosure. In an example, the additional supply 402 of pressurized liquefied gas, compressed gas or mixture of these is at a temperature ranging between 90 and 110 degrees Celsius and at a pressure of more than 13 bar or more than 14 bar or more than 15 bar.

[0028] Figure 11 is a schematic representation of a further example system according to the present disclosure. This example comprises the elements of Figure 3, functionally replacing the second evaporator 220 by an additional current flow channel 504 in the heat exchanger. In other words, the heat exchanger comprises an additional current flow channel 504 directly and selectively interconnecting each pressurized container with each other pressurized container. Such additional current flow channel 504 functions similarly to current flow channel 501 whereby the gas passing through this channel gets heated. This additional current flow channel is an alternative to an evaporator which participates in the functioning of the heat exchanger. While such an alternative is represented based on the schematic representation of the system of Figure 3, such additional current flow channel may be comprised in other systems according to this disclosure, including for example the system of Figure 10, leading to a system comprising two flow channels and two counter current flow channels. Such additional current flow channel 504 may be selectively operated by a valve such as valve 721 which may be open, closed, or partially open such as the other valves of the system of this disclosure. Such an additional current flow channel 504 may serve to relieve the functioning of an evaporator such as evaporator 210, for example when such evaporator should regain a temperature closer to ambient temperature, for example if and when such evaporator is covered with ice due to reaching a temperature well below ambient temperature. In addition to relieving the functioning of an evaporator, such additional current flow channel participates to the functioning of the heat exchanger according to the methods of this disclosure.

[0029] The valves may be operated manually or through a control system, which may comprise electro-mechanical elements or electronic elements. Control may take place with a controller, the controller comprising a processor and data storage, the data storage comprising a machine readable instruction set to operate the valves according to this disclosure. In examples according to this disclosure, each valve may interconnect elements of this disclosure directly and selectively. A direct connection may be via tubing between the valve and each element. A selective connection may be completely open through a valve and tubing, may be completely closed, or may be partially open. In some examples, the valves may interconnect elements of this disclosure indirectly, whereby other elements may be inserted between a valve and an interconnected element. An example of such other element is a filter.

[0030] The preceding description has been presented to illustrate and describe certain examples. Different sets of examples have been described; these may be applied individually or in combination, sometimes with a synergetic effect. This description is not intended to be exhaustive or to limit these principles to any precise form disclosed. Many modifications and variations are possible in light of the above teaching. It is to be understood that any feature described in relation to any one example may be used alone, or in combination with other features described, and may also be used in combination with any features of any other of the examples, or any combination of any other of the examples as long as they are covered by the appended claims.

Claims

1. A pressurizing method to cyclically modify pressure in a first, second and third containers, the method comprising repeating the following steps in a cycle:

a- supplying liquefied gas through a one way supply (300) to the first pressurized container (101), the first

pressurized container (101) being at a first pressure,

b- connect the first pressurized container (101) to an evaporator (210) to evaporate liquefied gas to produce a first fluid and increase pressure in the first pressurized container (101) to a second pressure,

c- connect the first pressurized container (101) with a consumer connection (400) via a channel (501) of a heat exchanger, the first fluid raising its temperature as it flows through the channel (501), the second pressure being higher than a pressure in the consumer connection (400),

d- connect the second pressurized container (103) containing a second fluid with the third pressurized container (102) via a counter current flow channel (502) of the heat exchanger, the second fluid reducing its temperature as it flows through the counter current flow channel (502), the pressure in the second pressurized container (103) being higher than the pressure in the third pressurized container (102), the second fluid passing through an expansion element (600) between the counter flow exchanger and the third pressurized container (102),

e- repeat the above steps using a circular permutation between the first, second and third containers, each container cycling through successive phases of being supplied with liquefied gas, evaporating liquefied gas, consumer connection and depressurisation.

2. The method according to claim 1, whereby the liquefied gas comprises cryogenic liquid natural gas and the first fluid comprises either pressurized liquefied natural gas or compressed natural gas.

3. The method according to any of the above claims, whereby the steps are implemented by opening and closing valves, the valves introducing losses of pressure.

4. The method according to any of the above claims, whereby the first pressure is of less than 6 bar

5. The method according to any of the above claims, whereby the second pressure is of more than 200 bar.

6. A system for providing a pressurized liquefied gas or compressed gas, the system being configured to carry out the method according to any of the above claims, the system comprising:

a supply connection (300) for the supply of liquefied gas;

three pressurized containers (101, 102, 103), an evaporator (210) and a heat exchanger;

a consumer connection (400) connected to the heat exchanger;

valves interconnecting the pressurized container (101, 102, 103) with the supply connection (300), with the evaporator (210), and with the heat exchanger;

an expansion element (600), and

the heat exchanger is a counter current flow heat exchanger having two inputs and two outputs, two inputs and a first output being connected to the pressurized containers (101, 102, 103), the expansion element being located between the first output and the pressurized containers, the second output being connected to the consumer connection.

7. The system of claim 6, further comprising a second evaporator (220), the second evaporator (220) being connected to each of the pressurized containers (101, 102, 103).

8. The system of claim 6, comprising a second (232) and a third (233) evaporator, each evaporator (231, 232, 233) being connected to a respective pressurized container (101, 102, 103).

9. The system of claim 6, whereby the evaporator (210) is connected to the second output of the heat exchanger via a valve.

10. The system of any of the above claims, whereby the expansion element (600) comprises a Joule-Thomson valve.

11. The system of any of the above claims, including an additional liquefied gas supply connection to an additional consumer connection (401).

12. The system of any of the above claims, whereby the supply connection (300) is a one way connection.

13. The system of any of the above claims, whereby the system is a pumpless system.

14. The system of any of the above claims, whereby the system further comprises an additional supply connection (402) connected to the expansion element (600) through an additional counter current flow channel (503) of the heat exchanger.
- 5 15. The system of any of the above claims, whereby the heat exchanger comprises an additional current flow channel (504) directly and selectively interconnecting each pressurized container with each other pressurized container.

Patentansprüche

1. Ein Druckbeaufschlagungsverfahren zum zyklischen Modifizieren des Drucks in einem ersten, zweiten und dritten Behälter, wobei das Verfahren das Wiederholen der folgenden Schritte in einem Zyklus umfasst:

- a- Zuführen von verflüssigtem Gas durch eine Einwegversorgung (300) zu dem ersten Druckbehälter (101), wobei der erste Druckbehälter (101) auf einem ersten Druck ist,
- b- Verbinden des ersten Druckbehälters (101) mit einem Verdampfer (210), um verflüssigtes Gas zu verdampfen, um ein erstes Fluid zu erzeugen und den Druck im ersten Druckbehälter (101) auf einen zweiten Druck zu erhöhen,
- c- Verbinden des ersten Druckbehälters (101) mit einem Verbraucheranschluss (400) über einen Kanal (501) eines Wärmetauschers, wobei das erste Fluid seine Temperatur erhöht, als es durch den Kanal (501) fließt, wobei der zweite Druck höher als ein Druck im Verbraucheranschluss (400) ist,
- d- Verbinden des zweiten Druckbehälters (103), der ein zweites Fluid enthält, mit dem dritten Druckbehälter (102) über einen Gegenstromkanal (502) des Wärmetauschers, wobei das zweite Fluid seine Temperatur reduziert, wenn es durch den Gegenstromkanal (502) fließt, wobei der Druck im zweiten Druckbehälter (103) höher als der Druck im dritten Druckbehälter (102) ist, wobei das zweite Fluid durch ein Expansionselement (600) zwischen dem Gegenstromtauscher und dem dritten Druckbehälter (102) strömt,
- e- Wiederholen der obigen Schritte unter Verwendung von einer kreisförmigen Permutation zwischen dem ersten, zweiten und dritten Behälter, wobei jeder Behälter zyklisch durch aufeinanderfolgende Phasen der Versorgung mit verflüssigten Gas, des Verdampfens von verflüssigtem Gas, des Verbraucheranschlusses und der Druckentlastung durchläuft.

2. Das Verfahren nach Anspruch 1, wobei das verflüssigte Gas kryogenes flüssiges Erdgas umfasst und das erste Fluid entweder mit Druck beaufschlagtes verflüssigtes Erdgas oder komprimiertes Erdgas umfasst.

3. Das Verfahren nach einem der vorstehenden Ansprüche, wobei die Schritte durch Öffnen und Schließen von Ventilen implementiert werden, wobei die Ventile Druckverluste einführen.

4. Das Verfahren nach einem der vorstehenden Ansprüche, wobei der erste Druck weniger als 6 bar beträgt.

5. Das Verfahren nach einem der vorstehenden Ansprüche, wobei der zweite Druck mehr als 200 bar beträgt.

6. Ein System zum Bereitstellen von einem mit Druck beaufschlagten verflüssigten Gas oder komprimierten Gas, wobei das System dazu konfiguriert ist, das Verfahren nach einem der vorstehenden Ansprüche durchzuführen, wobei das System Folgendes umfasst:

- einen Versorgungsanschluss (300) zur Versorgung mit verflüssigtem Gas;
- drei Druckbehälter (101, 102, 103), einen Verdampfer (210) und einen Wärmetauscher;
- einen mit dem Wärmetauscher verbundenen Verbraucheranschluss (400);
- Ventile, die den Druckbehälter (101, 102, 103) mit dem Versorgungsanschluss (300), mit dem Verdampfer (210) und mit dem Wärmetauscher verbinden;
- ein Expansionselement (600), und

wobei der Wärmetauscher ein Gegenstromwärmetauscher mit zwei Eingängen und zwei Ausgängen ist, wobei zwei Eingänge und ein erster Ausgang mit den Druckbehältern (101, 102, 103) verbunden sind, wobei das Expansionselement zwischen dem ersten Ausgang und den Druckbehältern angeordnet ist, wobei der zweite Ausgang mit dem Verbraucheranschluss verbunden ist.

7. Das System von Anspruch 6, ferner umfassend einen zweiten Verdampfer (220), wobei der zweite Verdampfer

(220) mit jedem der Druckbehälter (101, 102, 103) verbunden ist.

8. Das System von Anspruch 6, umfassend einen zweiten (232) und einen dritten (233) Verdampfer, wobei jeder Verdampfer (231, 232, 233) mit einem jeweiligen Druckbehälter (101, 102, 103) verbunden ist.

9. Das System nach Anspruch 6, wobei der Verdampfer (210) über ein Ventil mit dem zweiten Ausgang des Wärmetauschers verbunden ist.

10. Das System von einem der vorstehenden Ansprüche, wobei das Expansionselement (600) ein Joule-Thomson-Ventil umfasst.

11. Das System von einem der vorstehenden Ansprüche, einschließlich eines zusätzlichen Anschlusses zur Versorgung von verflüssigtem Gas zu einem zusätzlichen Verbraucheranschluss (401).

12. Das System von einem der vorstehenden Ansprüche, wobei der Versorgungsanschluss (300) ein Einweganschluss ist.

13. Das System von einem der vorstehenden Ansprüche, wobei das System ein pumpenloses System ist.

14. Das System von einem der vorstehenden Ansprüche, wobei das System ferner einen zusätzlichen Versorgungsanschluss (402) umfasst, der mit dem Expansionselement (600) durch einen zusätzlichen Gegenstromkanal (503) des Wärmetauschers verbunden ist.

15. Das System von einem der vorstehenden Ansprüche, wobei der Wärmetauscher einen zusätzlichen Stromkanal (504) umfasst, der jeden Druckbehälter direkt und selektiv mit jedem anderen Druckbehälter verbindet.

Revendications

1. Un procédé de pressurisation pour modifier cycliquement la pression dans un premier, un deuxième et un troisième conteneurs, le procédé comprenant la répétition des étapes suivantes dans un cycle :

a- fournir du gaz liquéfié moyennant une alimentation unidirectionnelle (300) au premier conteneur sous pression (101), le premier conteneur sous pression (101) étant à une première pression,

b- connecter le premier conteneur sous pression (101) à un évaporateur (210) pour évaporer le gaz liquéfié afin de produire un premier fluide et augmenter la pression dans le premier conteneur sous pression (101) jusqu'à une deuxième pression,

c- connecter le premier conteneur sous pression (101) à une connexion de consommateur (400) via un canal (501) d'un échangeur de chaleur, le premier fluide élevant sa température lors de son passage à travers le canal (501), la deuxième pression étant supérieure à une pression dans la connexion de consommateur (400),

d- connecter le deuxième conteneur sous pression (103) contenant un deuxième fluide avec le troisième conteneur sous pression (102) via un canal d'écoulement à contre-courant (502) de l'échangeur de chaleur, le deuxième fluide réduisant sa température lorsqu'il s'écoule à travers le canal d'écoulement à contre-courant (502), la pression dans le deuxième conteneur sous pression (103) étant supérieure à la pression dans le troisième conteneur sous pression (102), le deuxième fluide traversant un élément de détente (600) entre l'échangeur à contre-courant et le troisième conteneur sous pression (102),

e- répéter les étapes ci-dessus en utilisant une permutation circulaire entre les premier, deuxième et troisième conteneurs, chaque conteneur passant par des phases successives d'alimentation en gaz liquéfié, d'évaporation de gaz liquéfié, de connexion au consommateur et de dépressurisation.

2. Le procédé selon la revendication 1, dans lequel le gaz liquéfié comprend du gaz naturel liquide cryogénique et le premier fluide comprend soit du gaz naturel liquéfié sous pression, soit du gaz naturel comprimé.

3. Le procédé selon l'une quelconque des revendications ci-dessus, dans lequel les étapes sont mises en oeuvre en ouvrant et en fermant des vannes, les vannes introduisant des pertes de pression.

4. Le procédé selon l'une quelconque des revendications ci-dessus, dans lequel la première pression est inférieure à 6 bar.

5. Le procédé selon l'une quelconque des revendications ci-dessus, dans lequel la deuxième pression est supérieure à 200 bar.

6. Un système pour fournir un gaz liquéfié sous pression ou un gaz comprimé, le système étant configuré pour exécuter le procédé selon l'une quelconque des revendications ci-dessus, le système comprenant :

une connexion d'alimentation (300) pour l'alimentation en gaz liquéfié ;
trois conteneurs sous pression (101, 102, 103), un évaporateur (210) et un échangeur de chaleur ;
une connexion de consommateur (400) reliée à l'échangeur de chaleur ;
des vannes interconnectant le conteneur sous pression (101, 102, 103) avec la connexion d'alimentation (300),
avec l'évaporateur (210) et avec l'échangeur de chaleur ;
un élément de détente (600), et

l'échangeur de chaleur est un échangeur de chaleur à circulation à contre-courant ayant deux entrées et deux sorties, deux entrées et une première sortie étant connectées aux conteneurs sous pression (101, 102, 103), l'élément de détente étant situé entre la première sortie et les conteneurs sous pression, la deuxième sortie étant connectée à la connexion de consommateur.

7. Le système de la revendication 6, comprenant en outre un deuxième évaporateur (220), le deuxième évaporateur (220) étant relié à chacun des conteneurs sous pression (101, 102, 103).

8. Le système de la revendication 6, comprenant un deuxième (232) et un troisième (233) évaporateur, chaque évaporateur (231, 232, 233) étant relié à un conteneur sous pression respectif (101, 102, 103).

9. Le système de la revendication 6, dans lequel l'évaporateur (210) est relié à la deuxième sortie de l'échangeur de chaleur via une vanne.

10. Le système de l'une quelconque des revendications ci-dessus, dans lequel l'élément de détente (600) comprend une vanne Joule-Thomson.

11. Le système de l'une quelconque des revendications ci-dessus, comprenant une connexion d'alimentation en gaz liquéfié additionnelle à une connexion de consommateur additionnelle (401).

12. Le système de l'une quelconque des revendications ci-dessus, dans lequel la connexion d'alimentation (300) est une connexion unidirectionnelle.

13. Le système de l'une quelconque des revendications ci-dessus, dans lequel le système est un système sans pompe.

14. Le système de l'une quelconque des revendications ci-dessus, dans lequel le système comprend en outre une connexion d'alimentation additionnelle (402) connectée à l'élément de détente (600) via un canal d'écoulement à contre-courant additionnel (503) de l'échangeur de chaleur.

15. Le système de l'une quelconque des revendications ci-dessus, dans lequel l'échangeur de chaleur comprend un canal de circulation à courant additionnel (504) interconnectant directement et sélectivement chaque conteneur sous pression avec chaque autre conteneur sous pression.

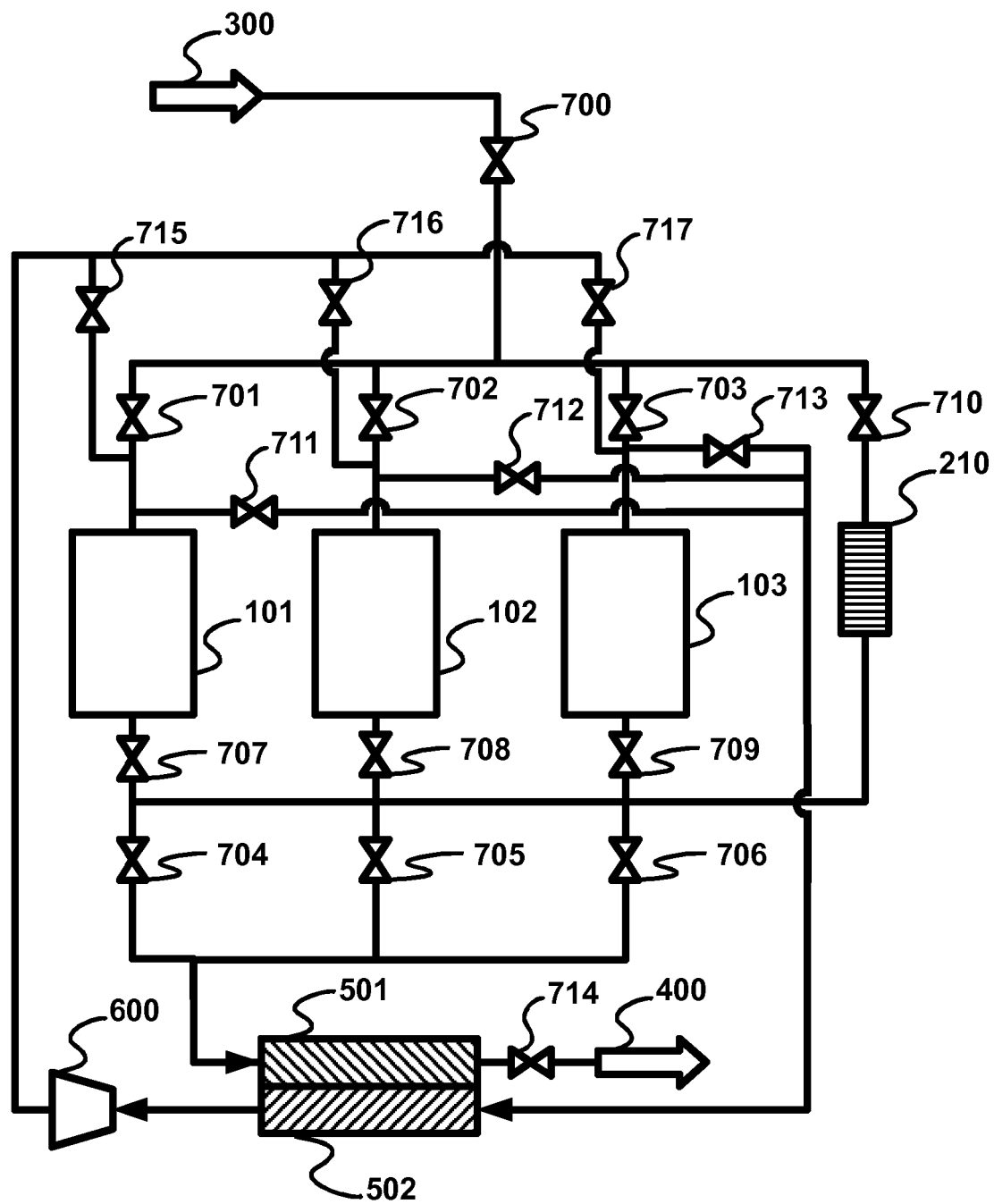


FIG. 1

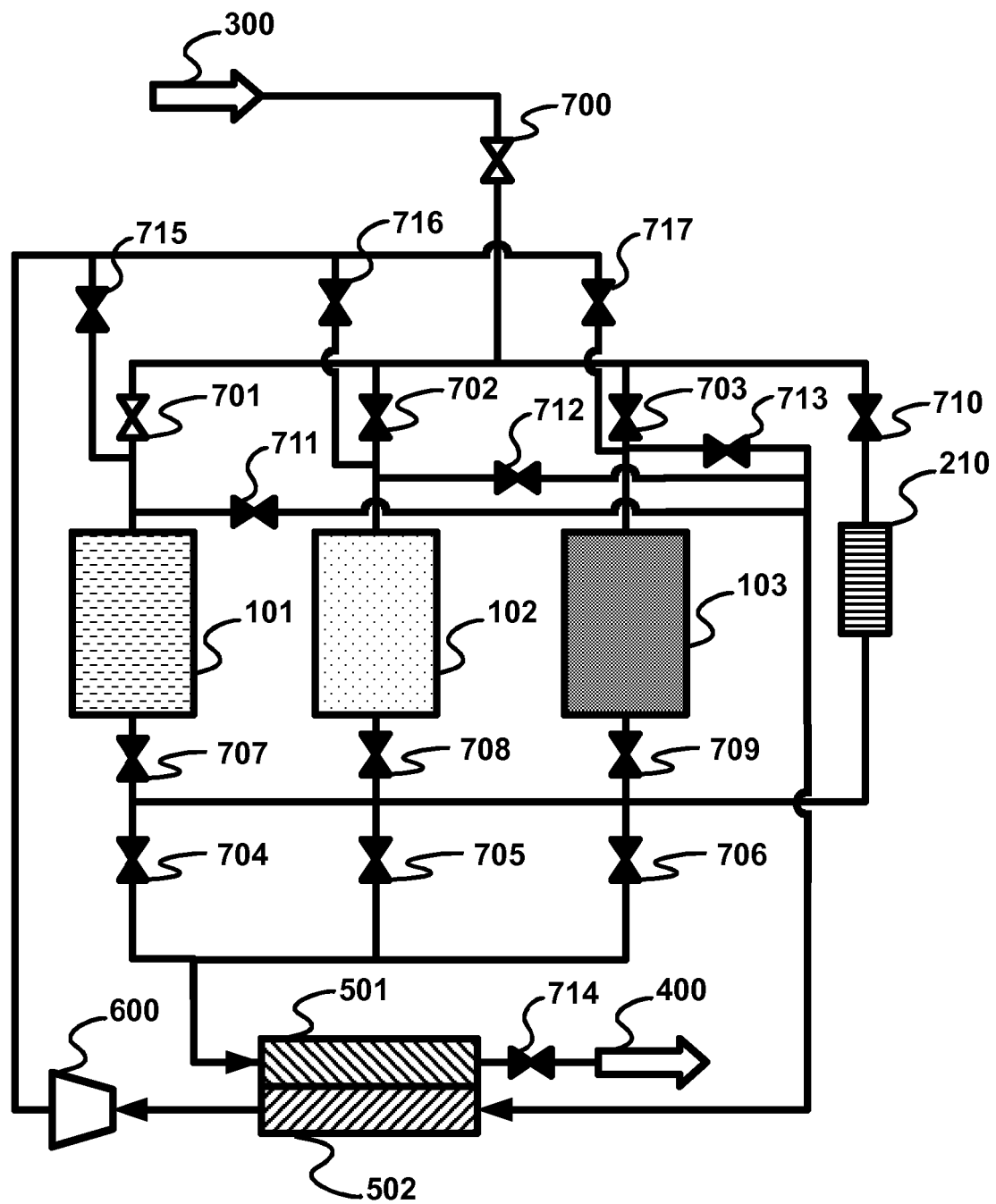


FIG. 2a

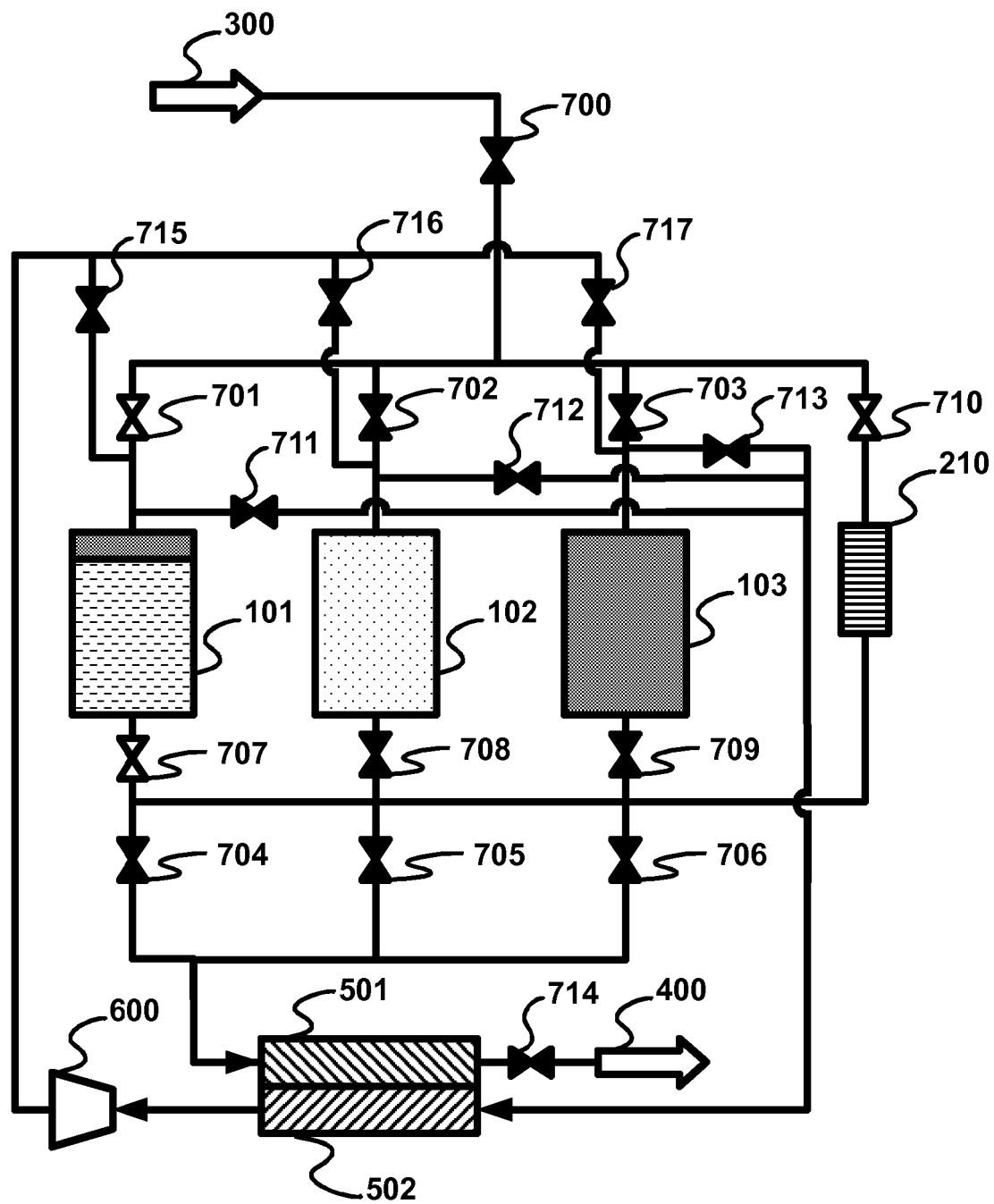


FIG. 2b

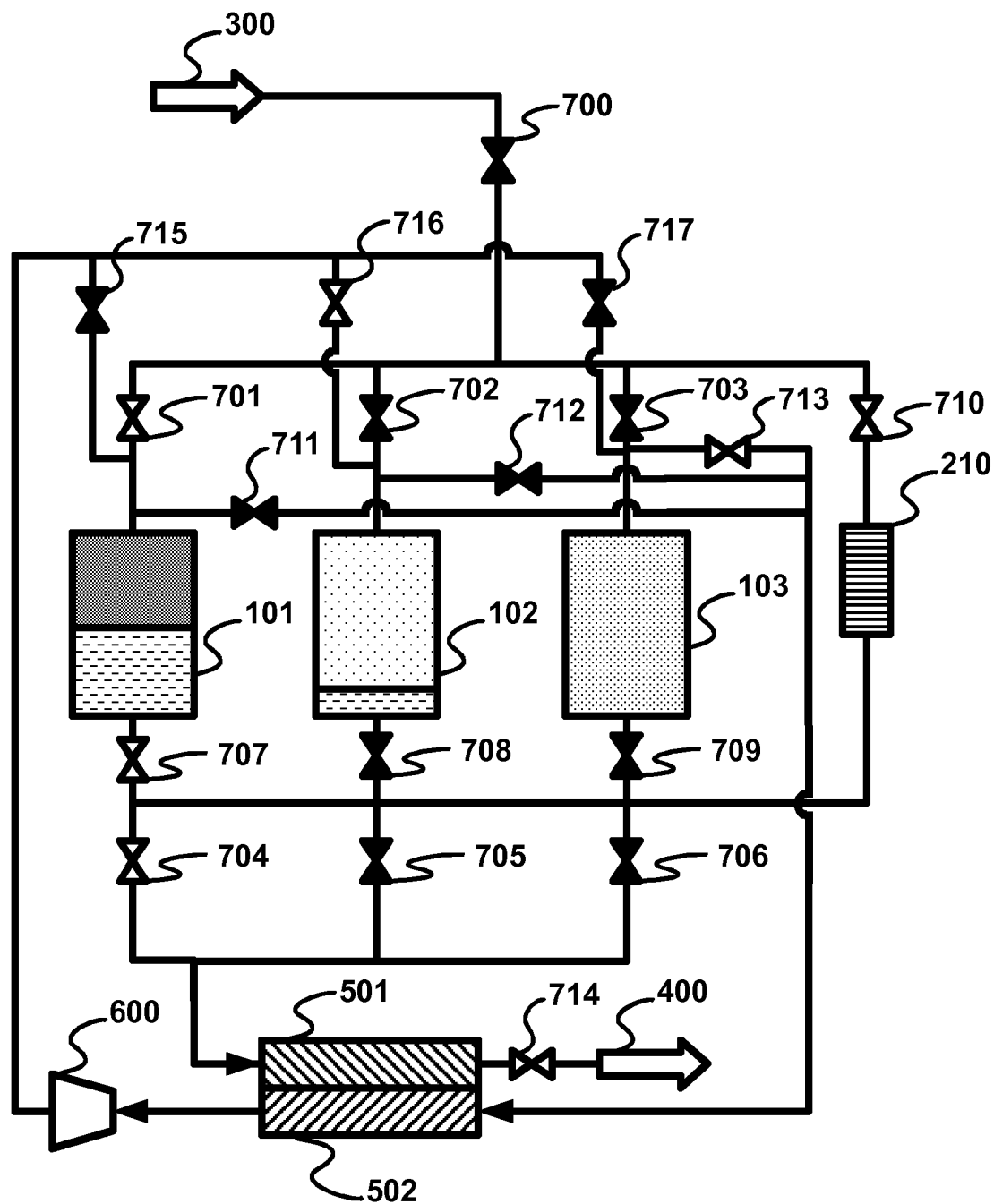


FIG. 2c

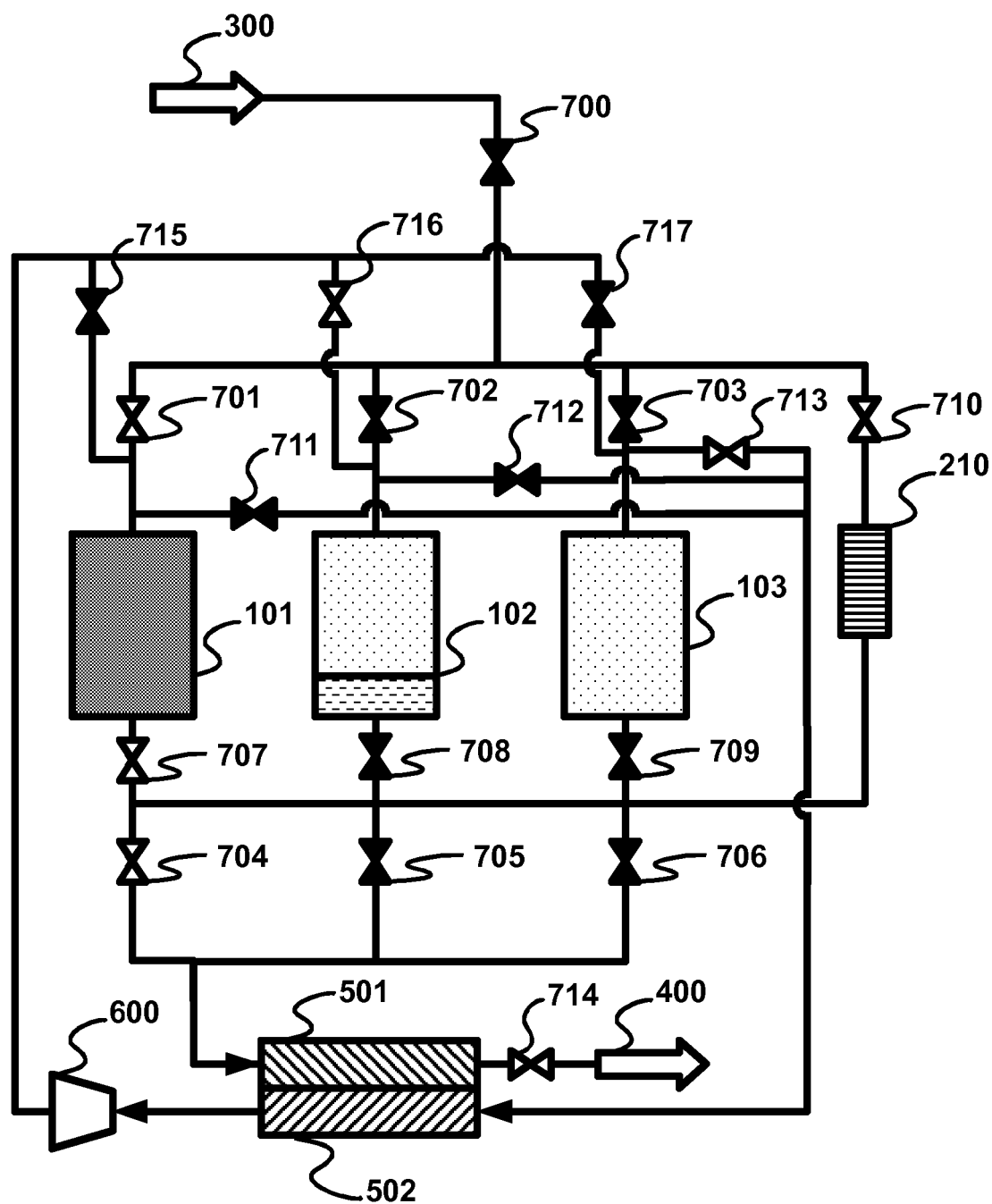


FIG. 2d

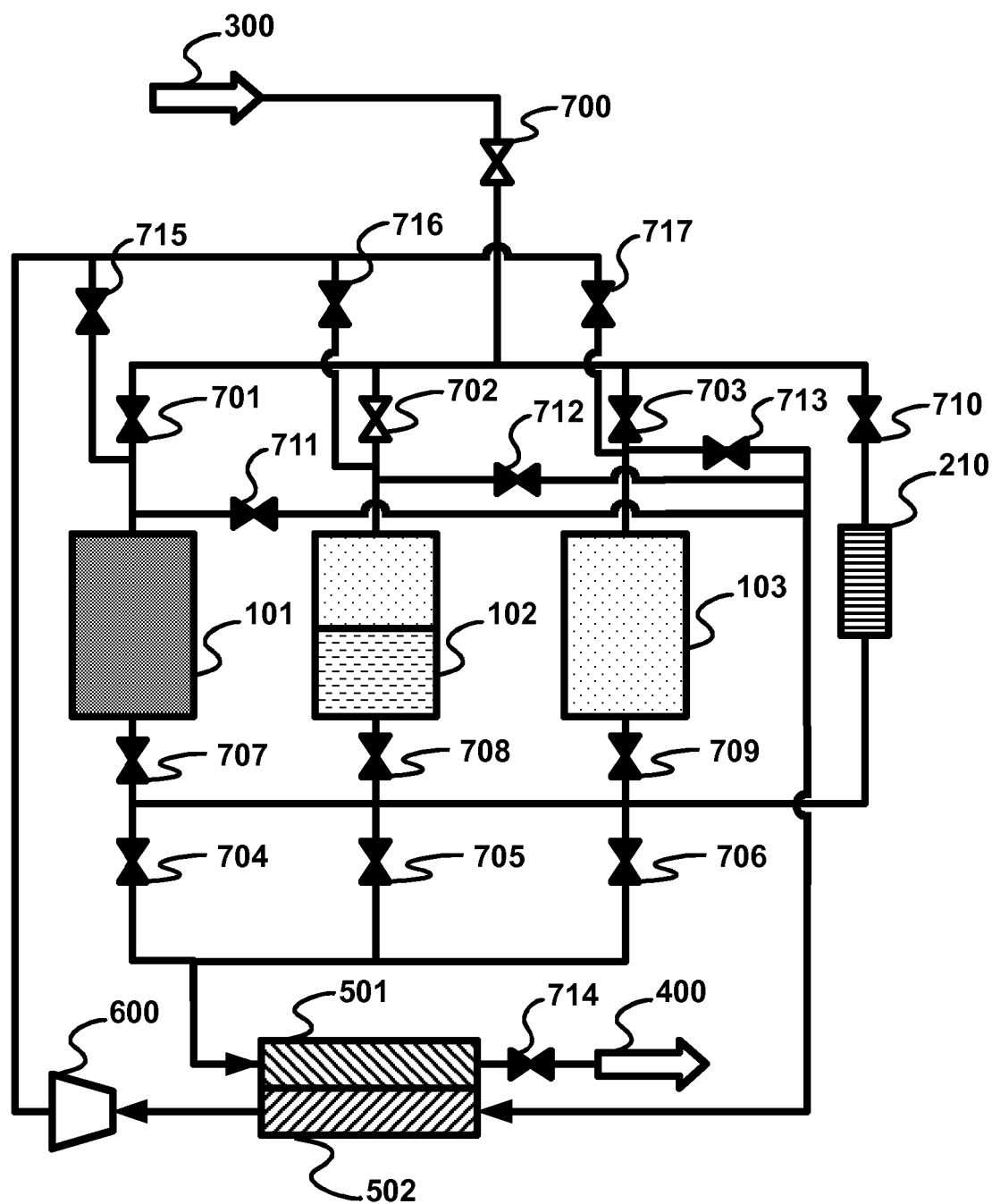


FIG. 2e

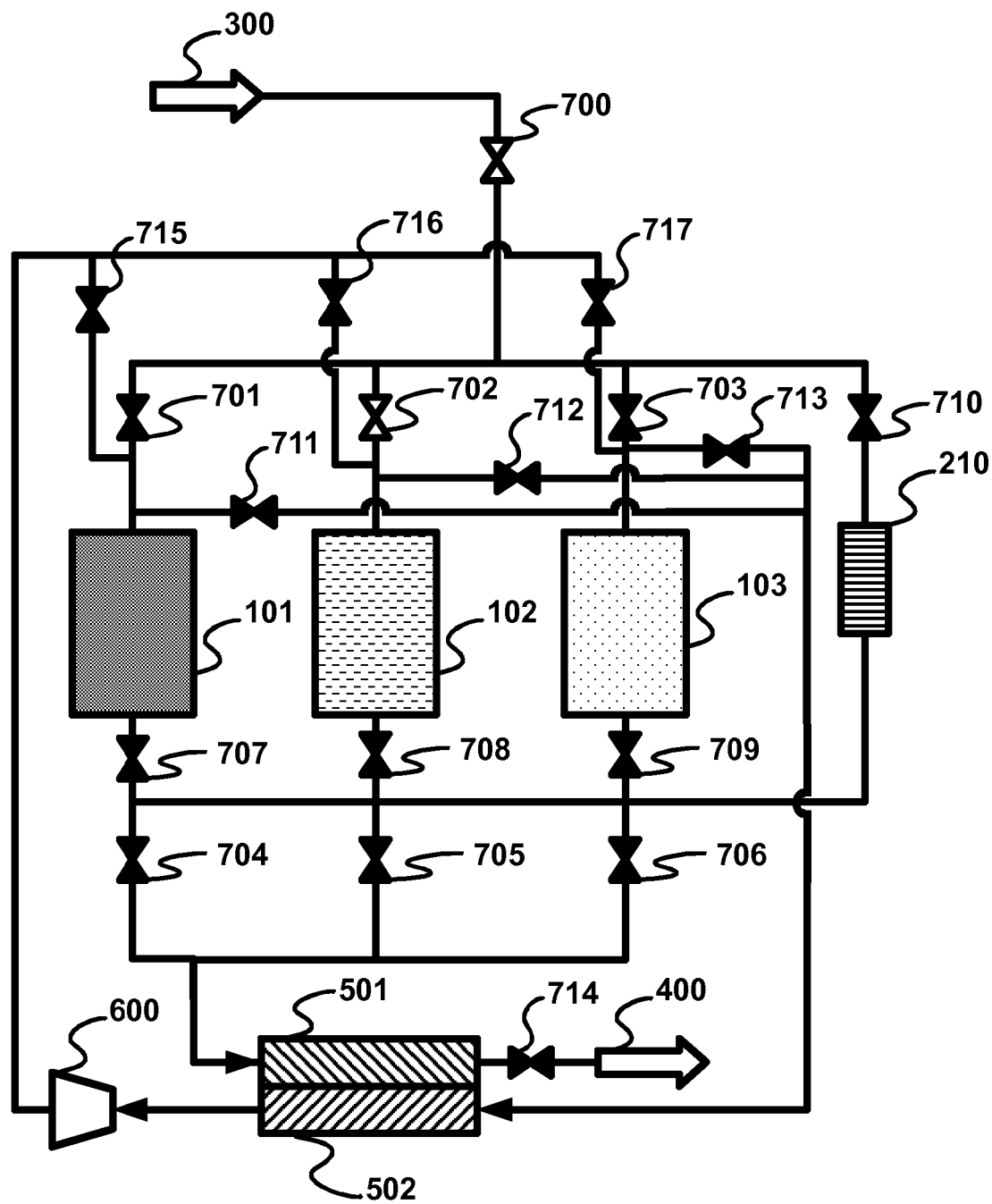


FIG. 2f

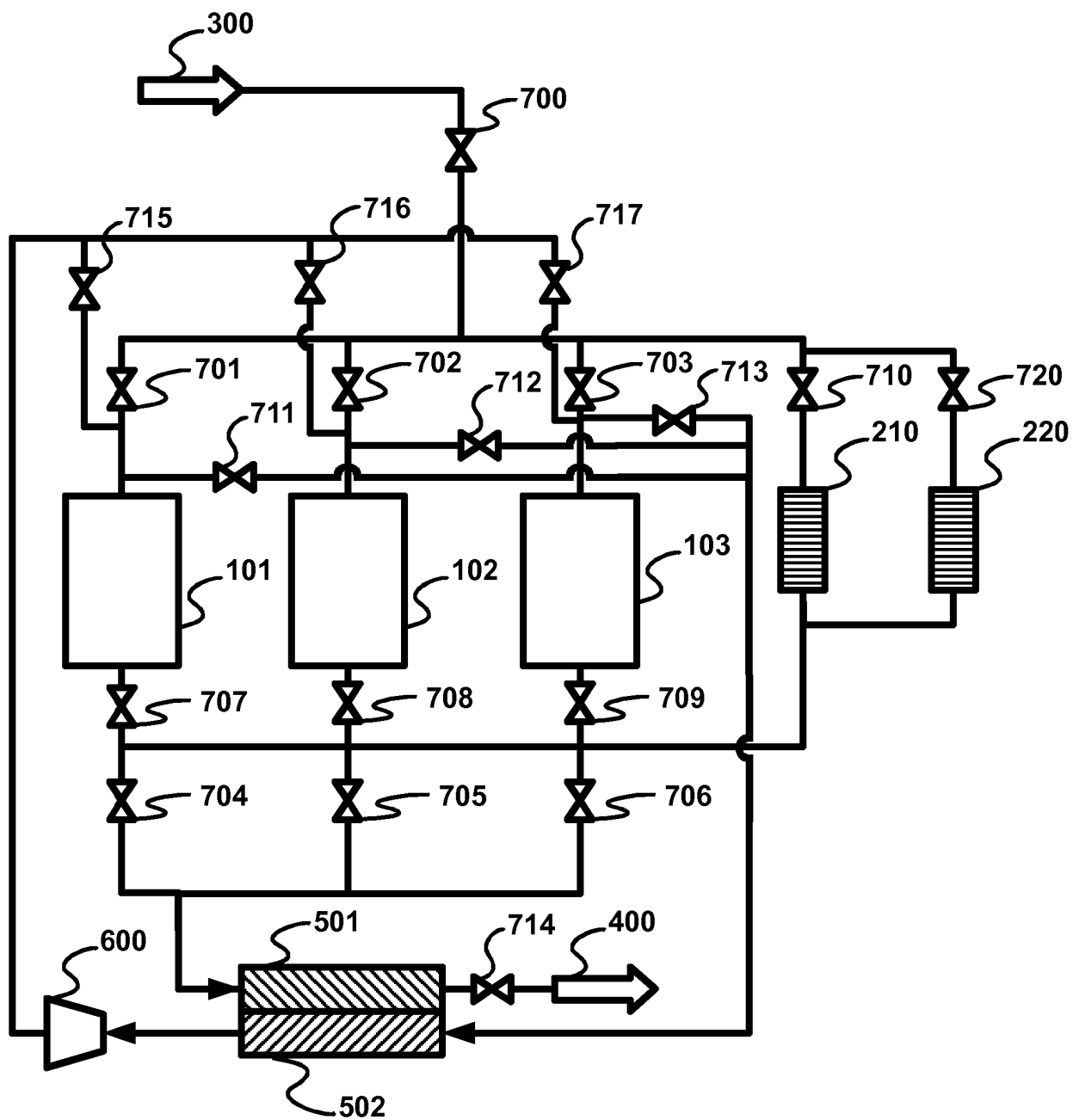


FIG. 3

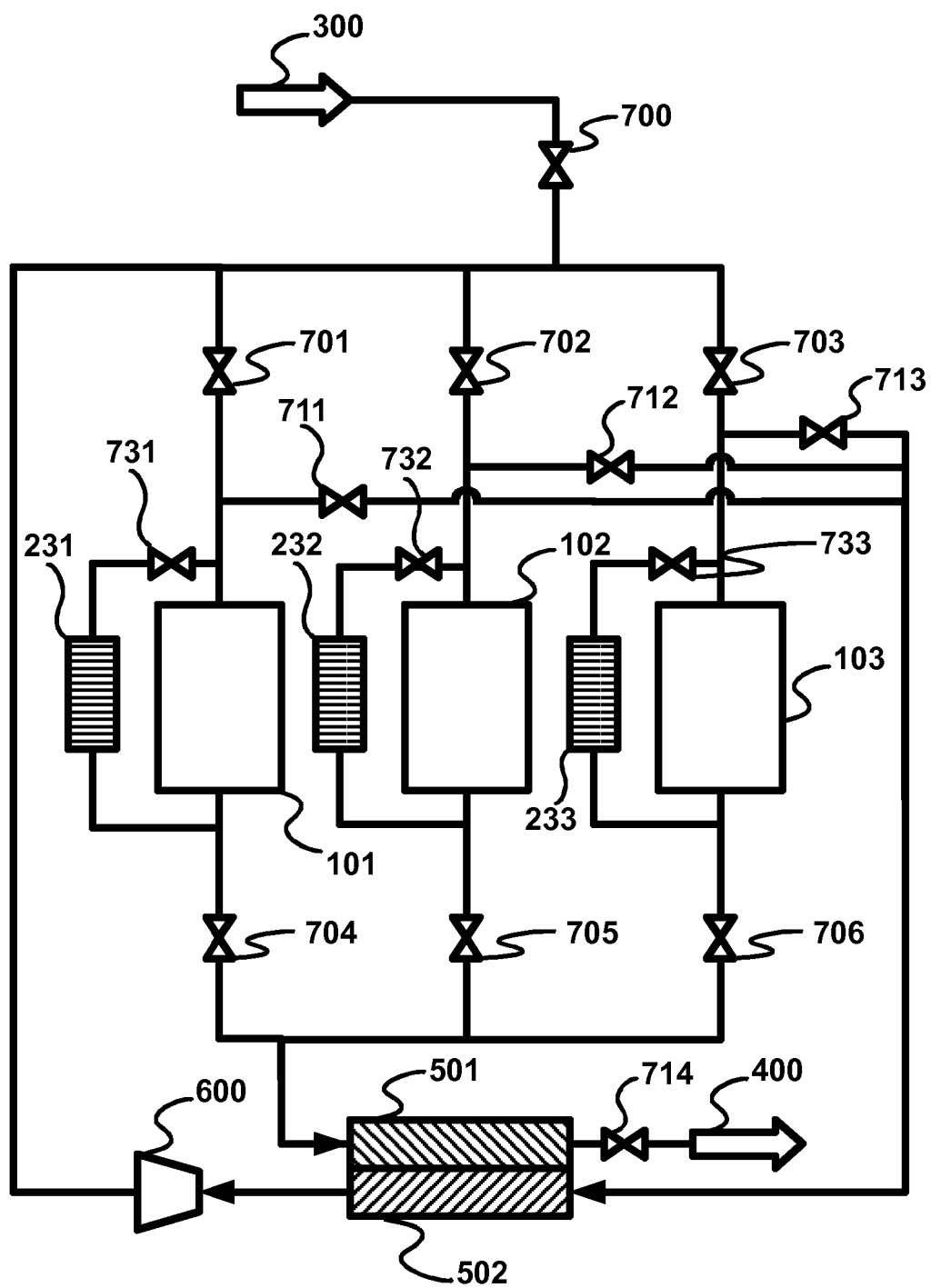


FIG. 4

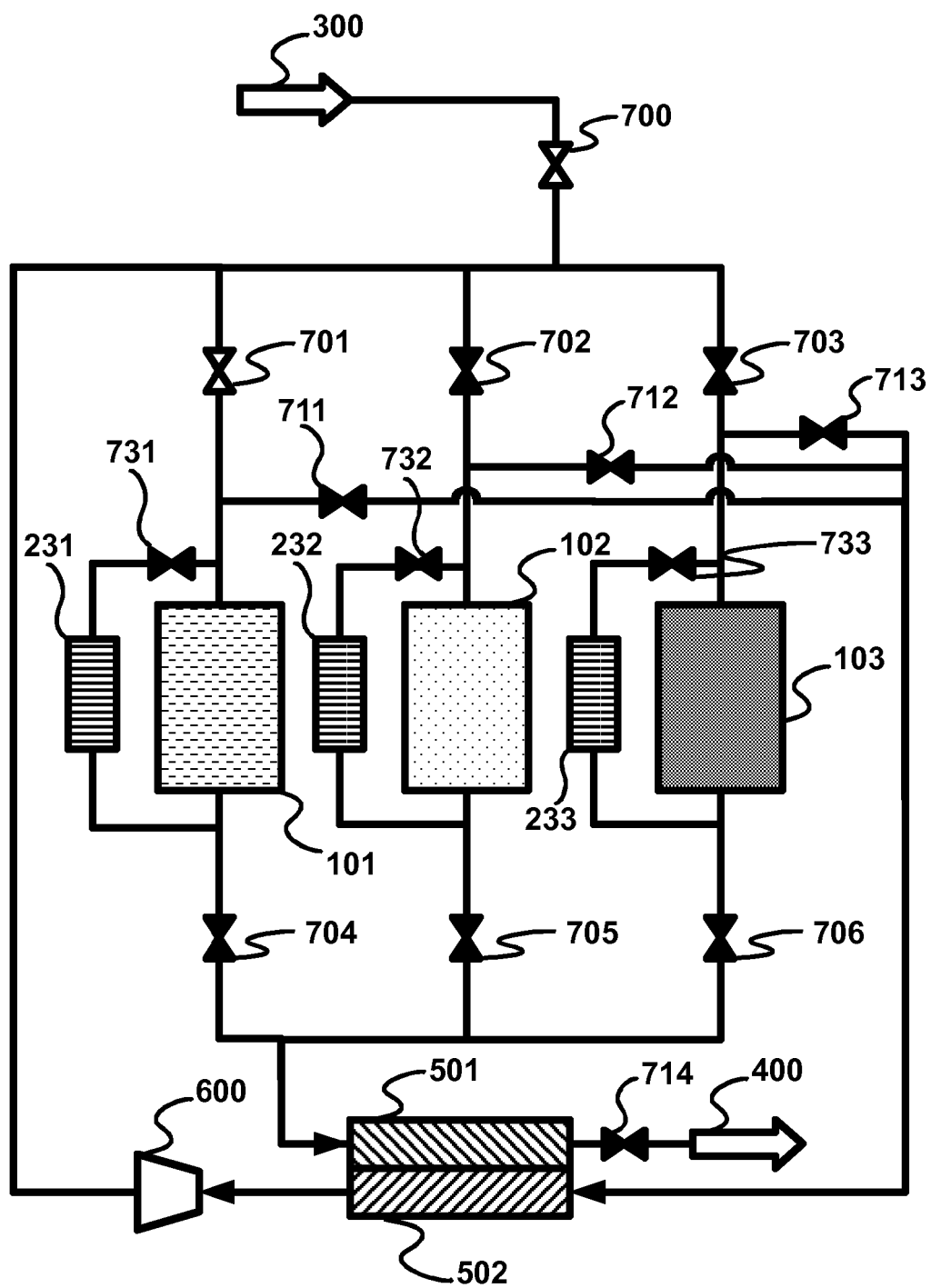


FIG. 5a

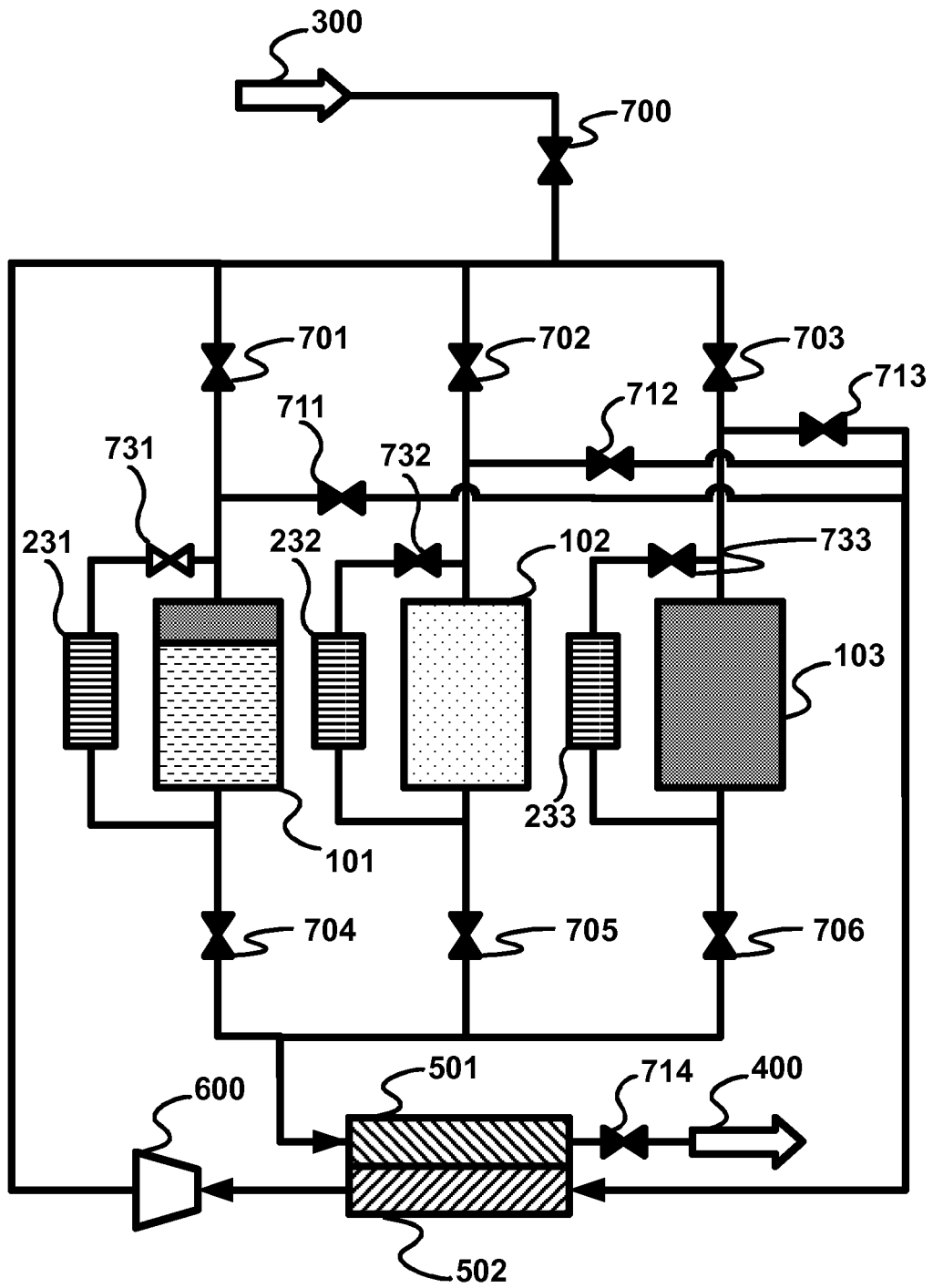


FIG. 5b

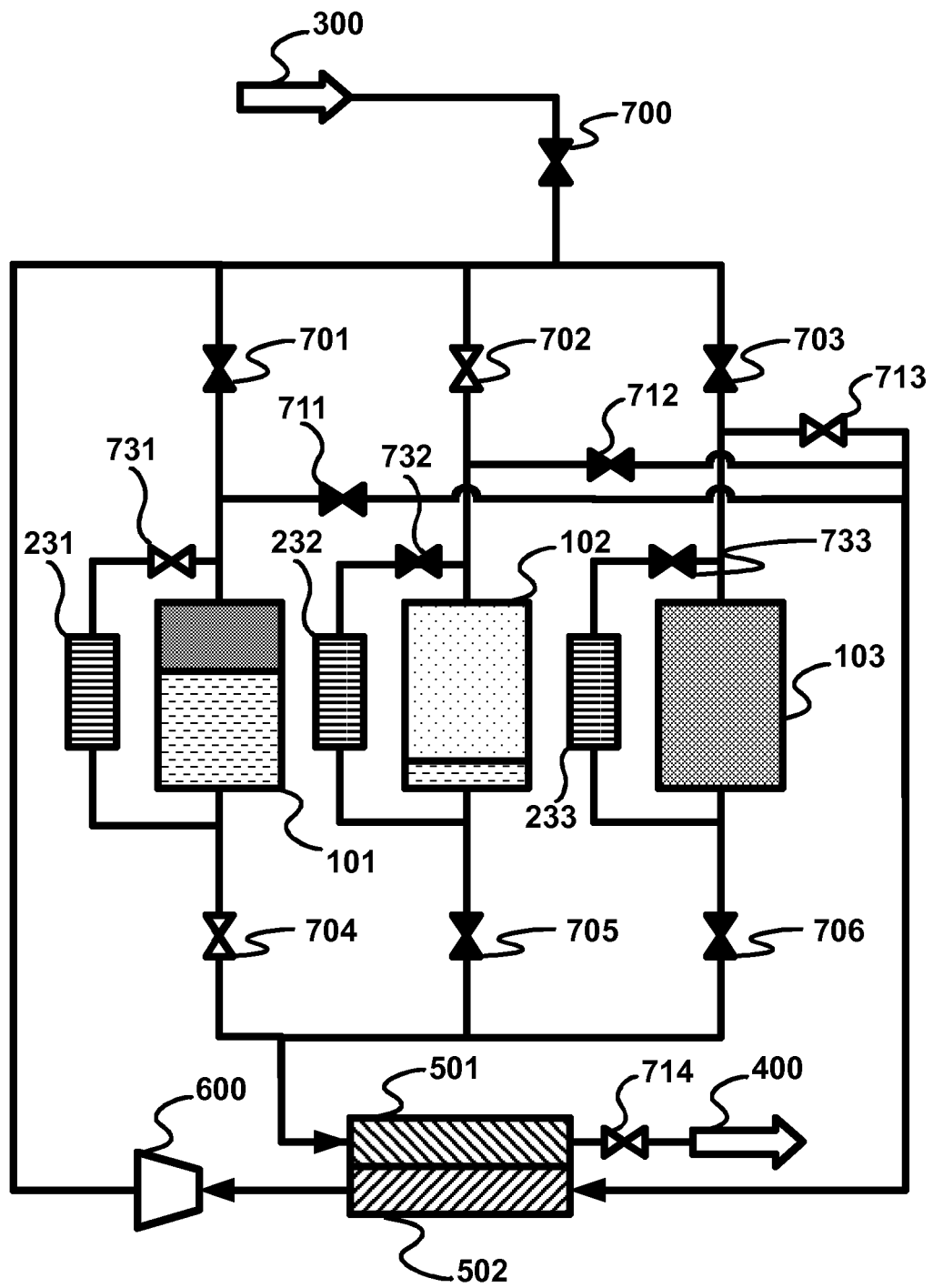


FIG. 5c

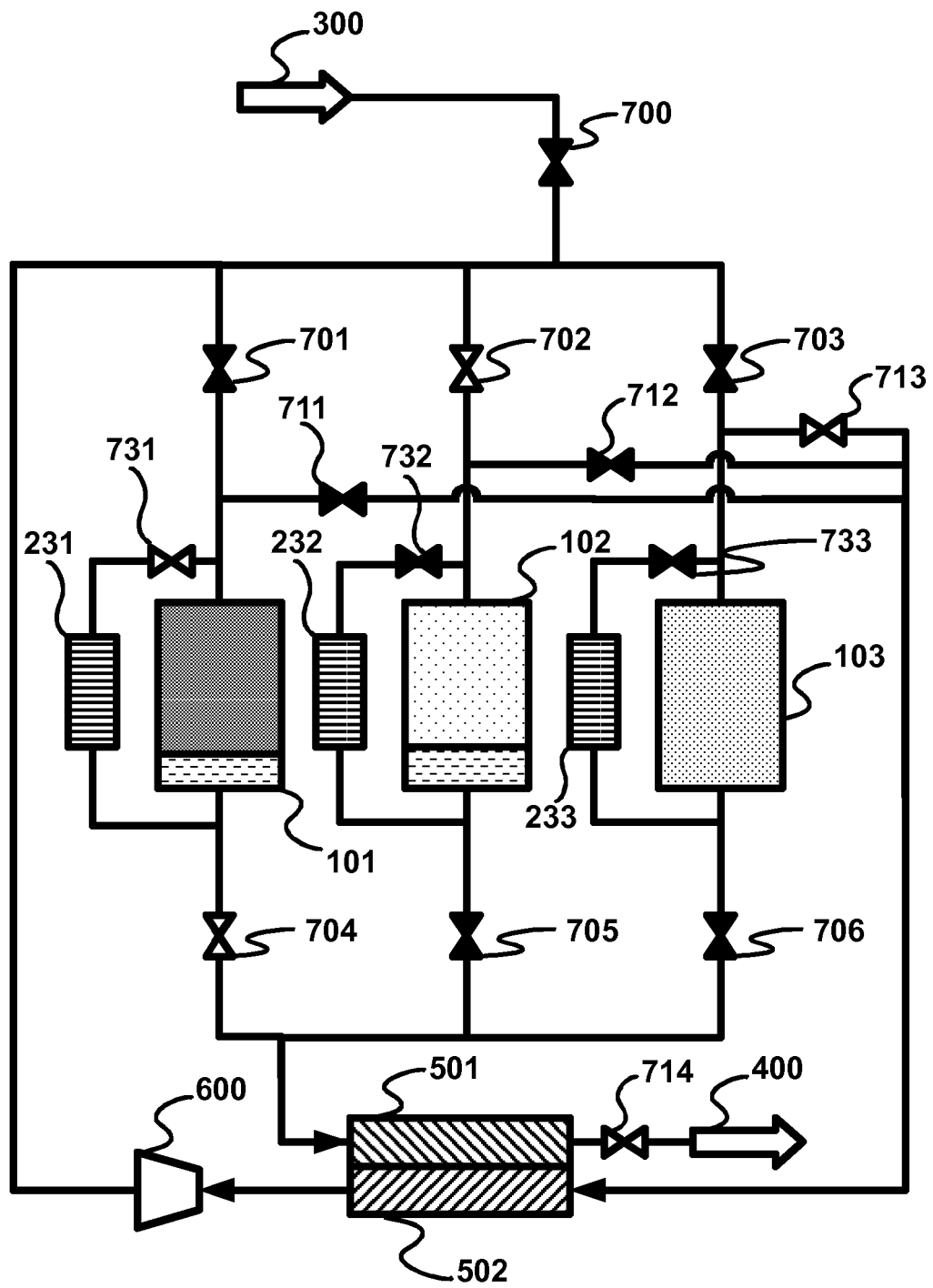


FIG. 5d

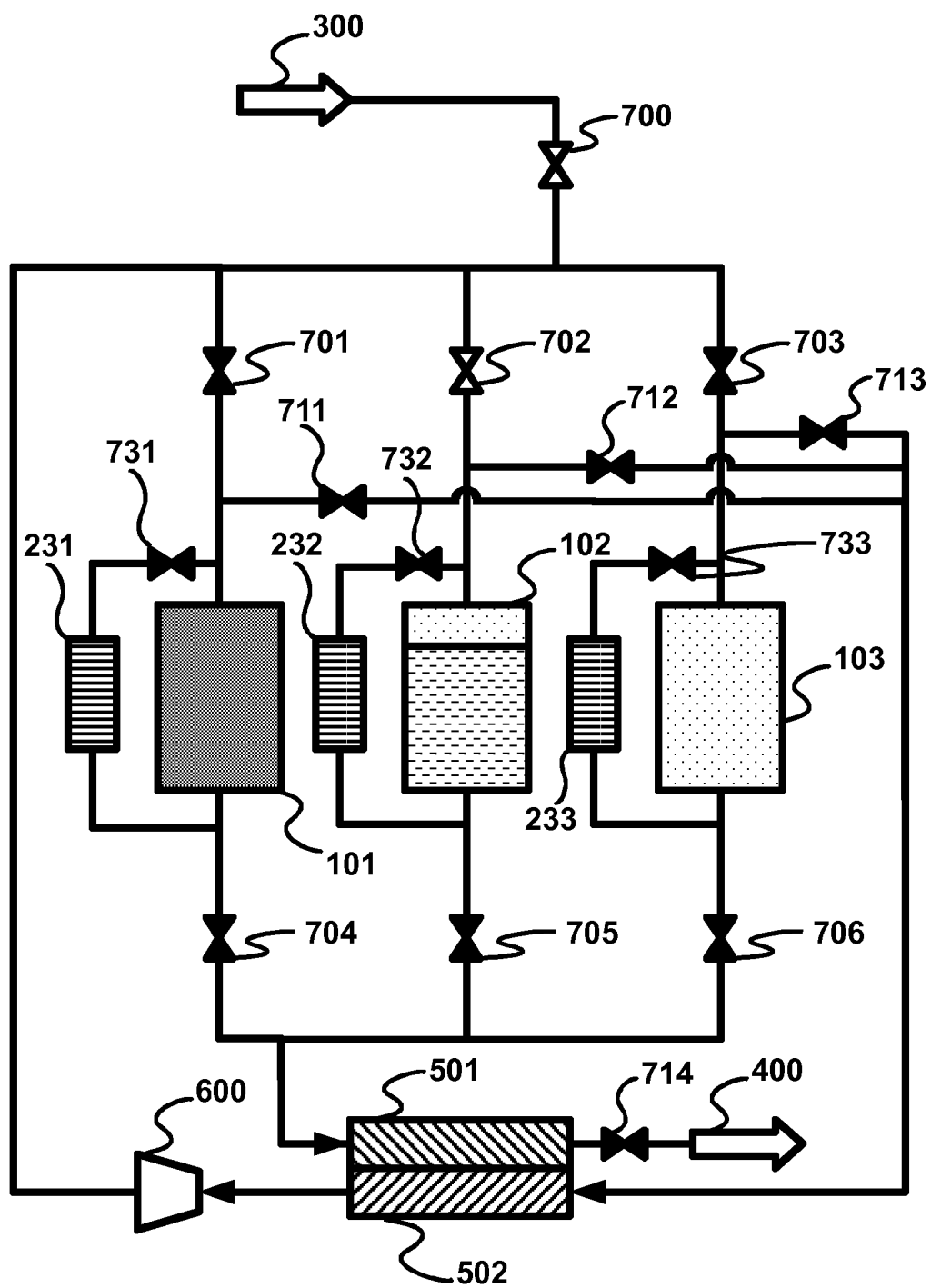


FIG. 5e

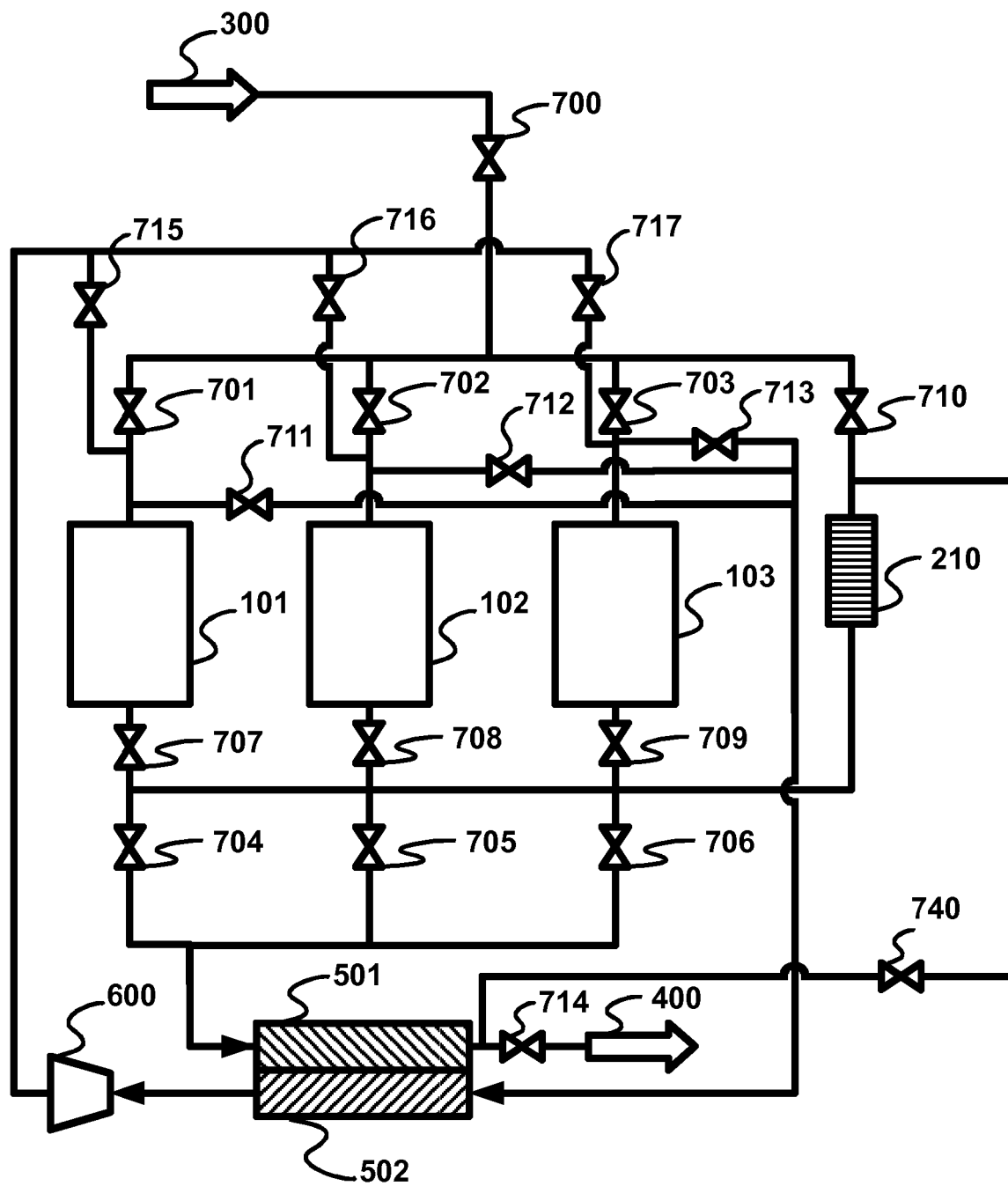


FIG. 6

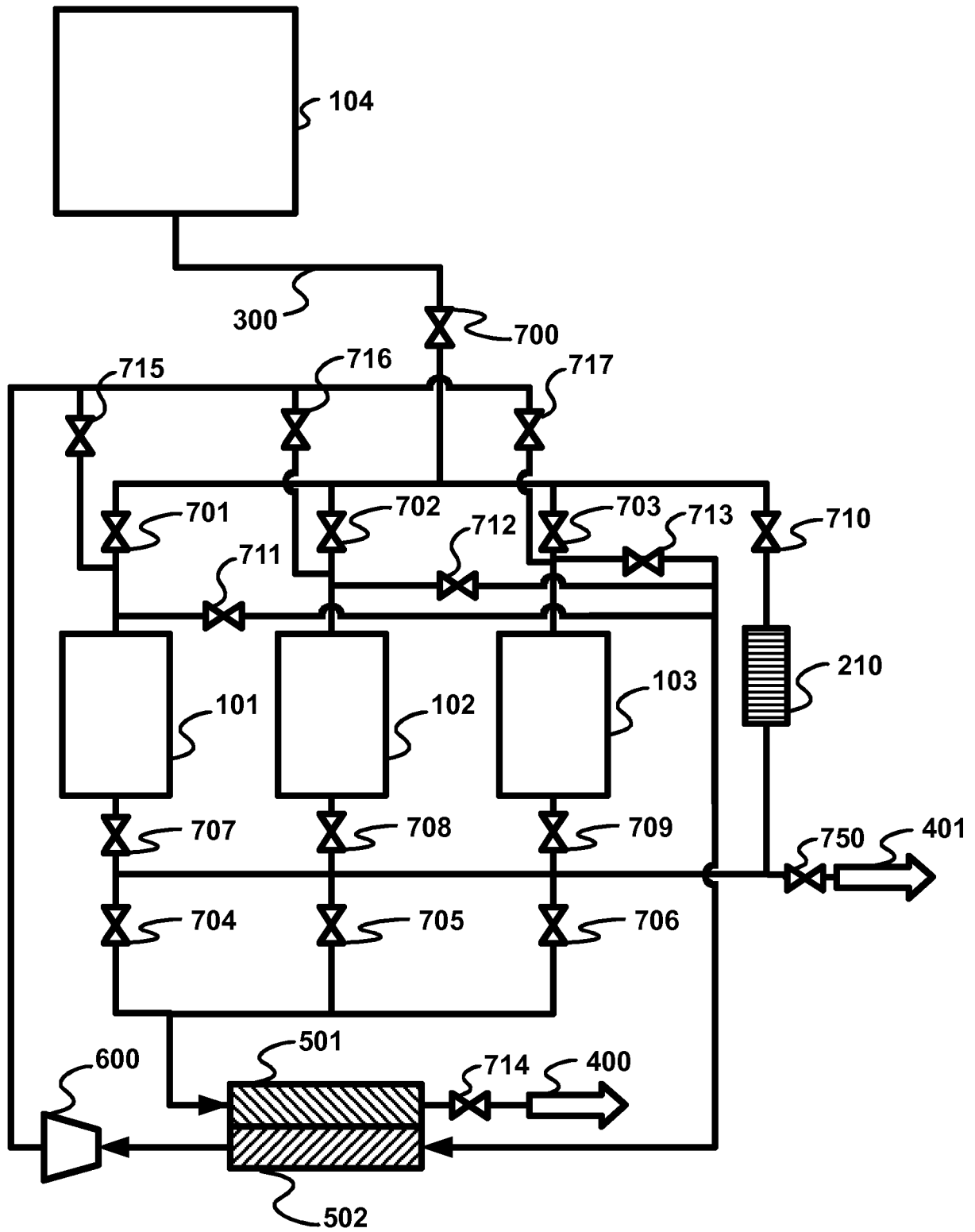
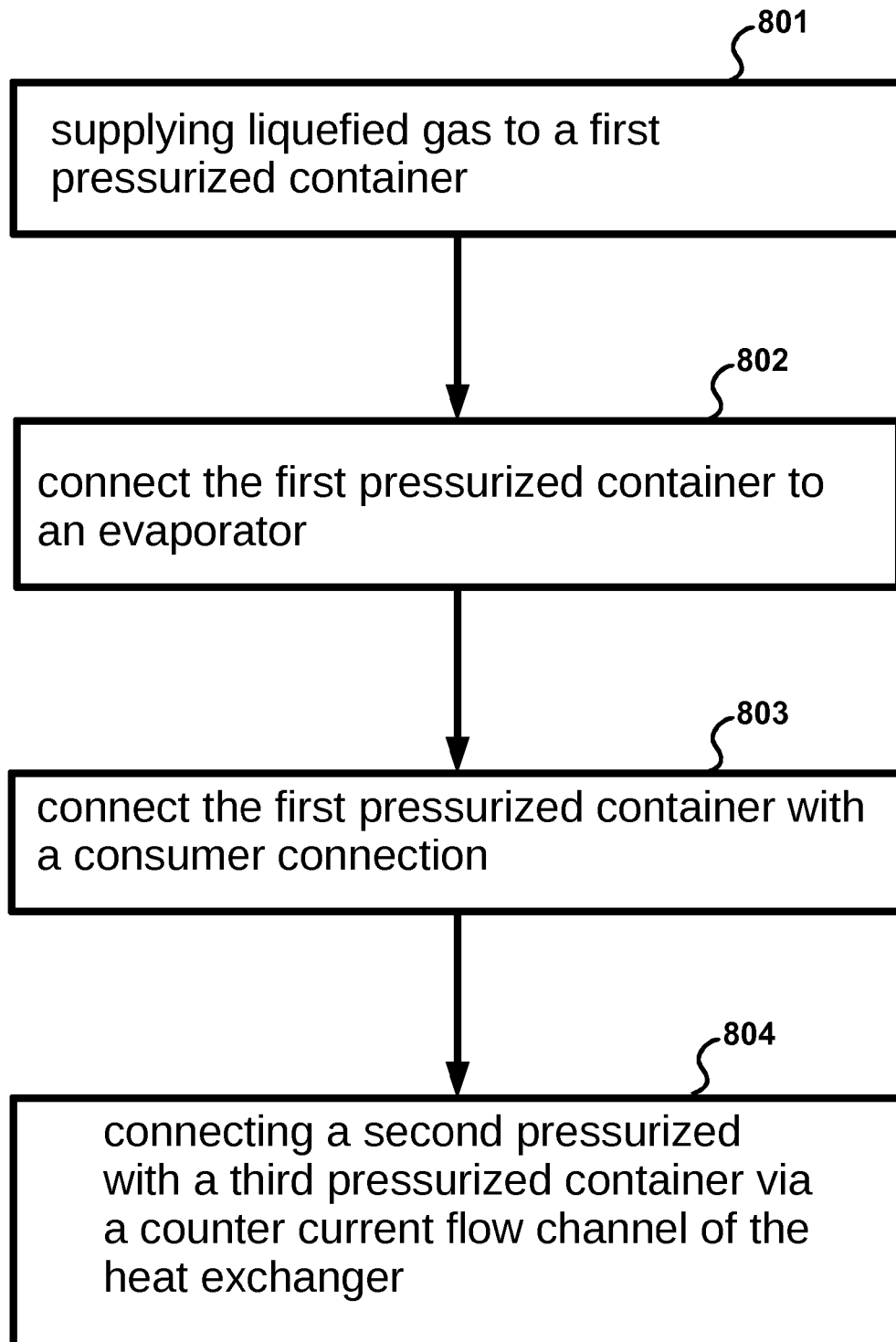


FIG. 7

**FIG. 8**

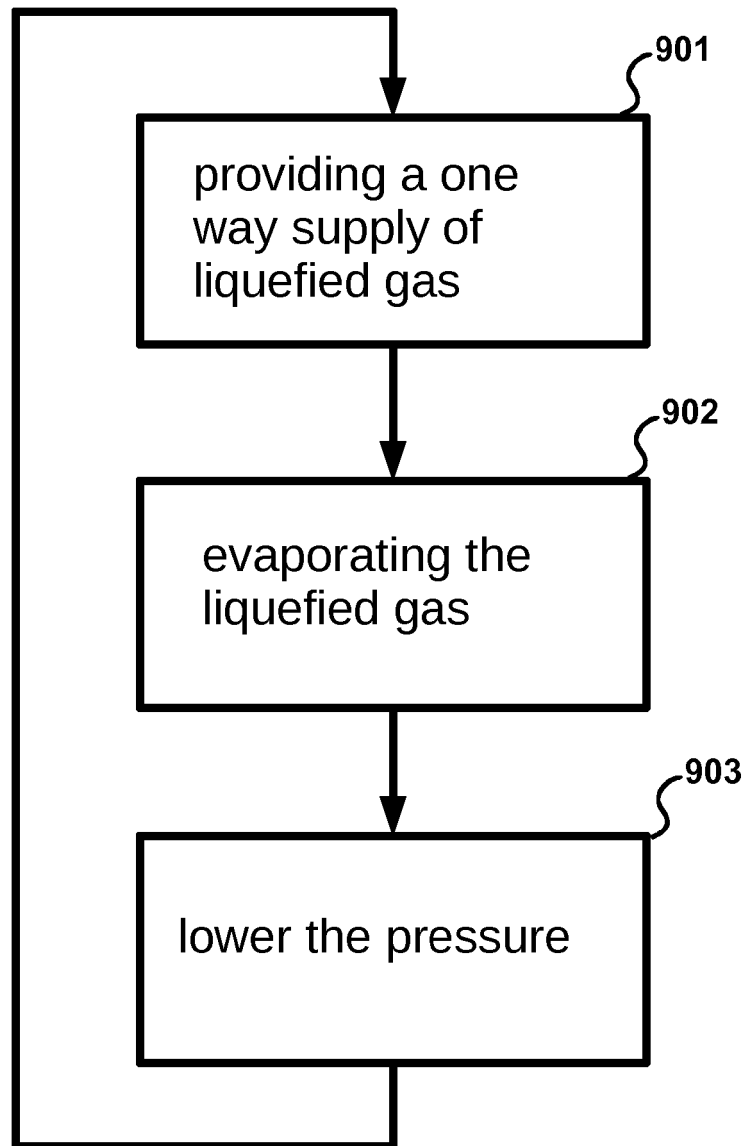


FIG. 9

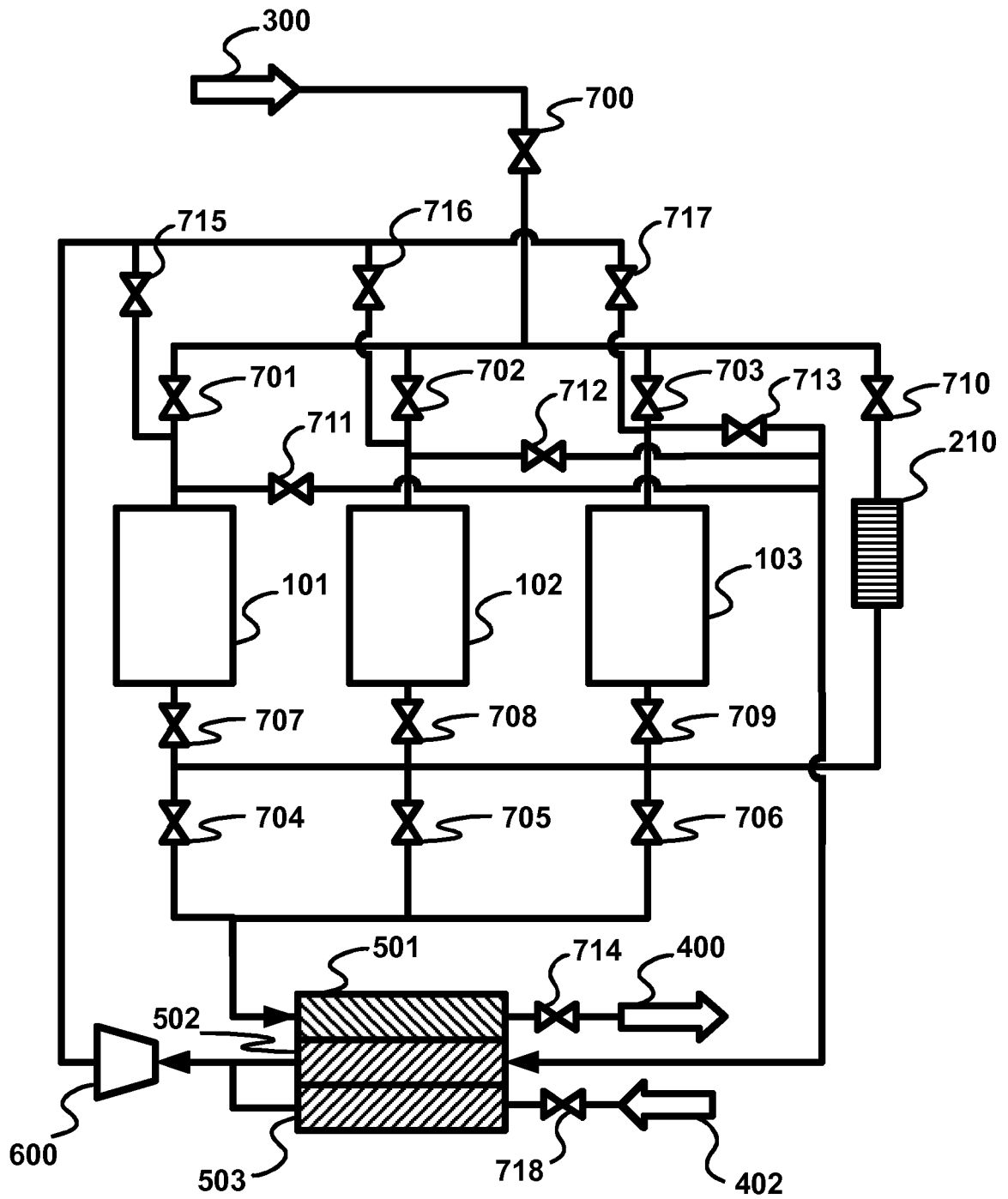


FIG. 10

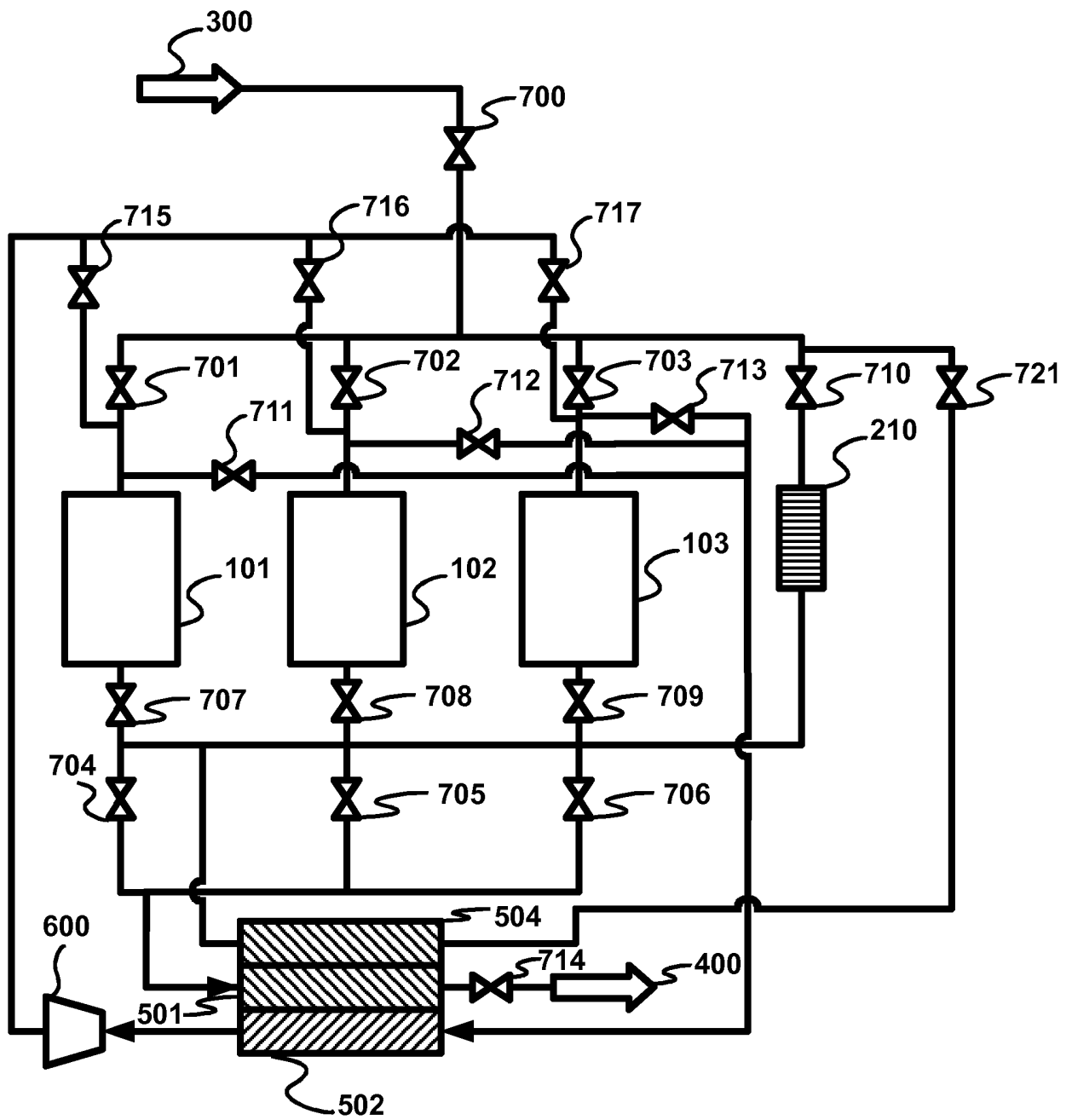


FIG. 11

REFERENCES CITED IN THE DESCRIPTION

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