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(54) High and low pressure pumping systems for cryogenic or liquefied gases

(57) High and low pressure pumping systems for cryogenic or liquefied gases comprise at least one cryogenic tank (1) in which the liquefied cryogenic gas is stored at low pressure and at least one vaporizer (2) which is connected to the gas offtake region located downstream of

the system. The systems comprise: at least one insulated tank (S; S1) which is interposed between a cryogenic tank (1) and a vaporizer (2); valves (V1, V2, V; V1, V3, V13) for connecting the tank (S; S1) to the tank (1) and valves (V3, V4; V2, V4) for connecting the tank (S; S1) to the vaporizer (2).

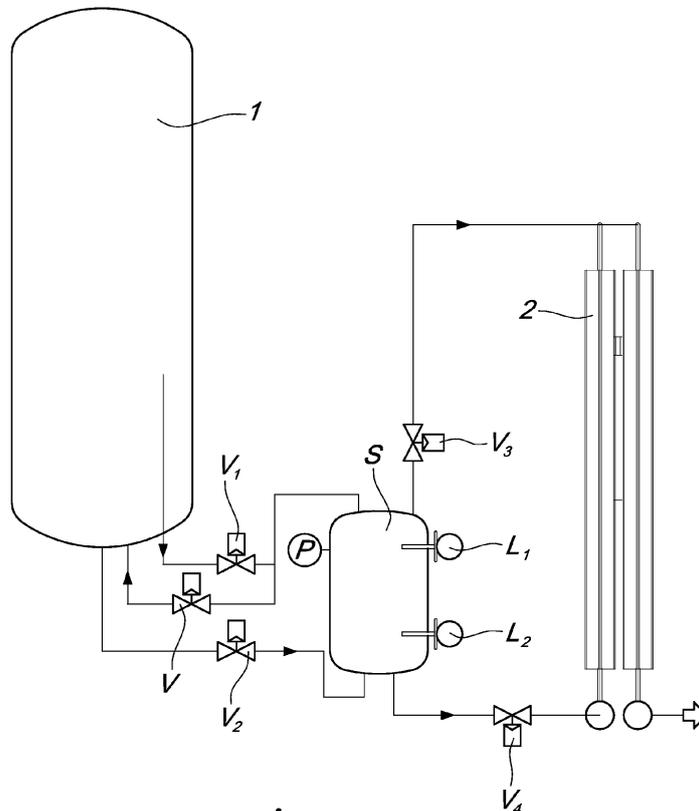


Fig. 1

EP 2 696 126 A2

Description

[0001] The use is now widespread of bottles containing compressed gas at high pressure, such as for example oxygen and nitrogen for technical use or methane for automobile use. Such gas bottles, in order to contain significant quantities of gas, are typically filled at pressures comprised between 200 and 300 bar, and such filling occurs, by compression, usually via two separate methods: 1) directly in gaseous form, by taking the gas from pipes with the help of mechanical compressors, such as for example occurs with methane gas for vehicle engines; 2) by taking the gas in liquid form from cryogenic tanks, which make it possible to store and move large quantities of gas in a reduced space, with the help of pumps that compress the liquefied gas under high pressure in order to transfer it to a vaporization system that can be atmospheric or based on a liquid exchanger. The liquefied gas, in passing through the vaporizer, evaporates absorbing the necessary heat from the air or from the liquid of the exchanger itself, in order to typically arrive at a storage/damping at high pressure, which is drawn from by the system for filling the bottles intended for the end user.

[0002] In both systems it is necessary to have an electric motor of adequate power, which is adapted to compress the compressed or liquefied gas up to pressures that can exceed 300 bar, with an energy consumption that is naturally very high.

[0003] Furthermore, such systems, which are selected depending on whether a gas has to be compressed in gaseous form or in liquefied form, also have, in addition to the drawback of high energy consumption, a second drawback which is no less important, represented by the wear of the parts in motion, which necessitate frequent and costly maintenance.

[0004] In order to prevent the above drawbacks and contain the costs of installation, electricity and maintenance, the aim of the present invention is to improve the system of pumping liquefied cryogenic gases, by enabling the correct delivery of the product at the right pressure with reduced filling times, extremely reduced energy consumption and near-zero maintenance.

[0005] In order to obtain such outcome a gas transfer and pressurization system has been developed and improved which takes advantage of the incompressibility of liquids and the energy already available in large quantities in the cryogenic gas itself, which is recovered during the expansion of the gas in the transition from the liquid phase to the gaseous phase at the critical temperature (an increase in volume of 300-600 times).

[0006] The principle is very simple, in that it takes advantage of the property of liquefied gases to increase their pressure during the transition from the liquid state to the gaseous state when they are confined in an enclosed volume and their temperature is increased.

[0007] Thanks to this principle, it is possible to increase the pressure of a liquefied gas using only the heat produced by the difference between the temperature of that

liquefied cryogenic gas and the ambient temperature, without using pumps or compressors.

[0008] The system consists in withdrawing from the storage tank, through the difference in pressure, a portion of cryogenic liquefied gas in order to feed it into a small storage tank; subsequently, the liquefied cryogenic gas contained in the small tank will be caused to vaporize, by supplying heat from the environment, and thus obtaining an increase in the pressure and a change of state from liquid to gas; the gas thus obtained, thanks to its pressure, will be transferred to a gas storage tank, balancing out the different pressures between the two.

[0009] In order to be able to introduce more liquefied cryogenic gas from the storage tank to the small expansion tank and continue the cycle, it will be necessary to decrease the pressure of the small storage tank by making part of the gas in the main tank return and then recondensing it, or by making it recondense in a second small tank that was previously filled with liquefied gas destined for vaporization.

[0010] The above aim is achieved both by a system as claimed in claim 1 and a method as claimed in claim 4.

[0011] In any case, the solutions outlined above will be explained in more detail with the help of the accompanying two tables of drawings which include, for the purposes of non-limiting example:

- Figure 1, which schematically shows a first embodiment of a system for high-pressure pumping and regasification of liquefied cryogenic gas for filling high pressure bottles;
- Figure 2, which schematically shows a second embodiment of a system for high-pressure pumping and regasification of liquefied cryogenic gas for filling high pressure bottles.

[0012] In the example in Figure 1, the liquefied cryogenic gas is kept at low temperature (typically from -160 to -190°C depending on the type of gas) in the cryogenic tank 1 with storage pressures of normally just a few bar. With the system ready for operation, the vaporizer 2, which is connected to the downstream usage station, is kept at a pressure comprised between 250 and 300 bar, while the valves V, V1, V2, V3 and V4 are kept closed.

[0013] When a withdrawal of gas occurs downstream of the system, for example owing to the filling of bottles, there is naturally a fall in pressure in the vaporizer 2. Upon reaching the preset minimum pressure threshold, the control system commands the opening of the valves V and V2, which causes, thanks to the simple "thermosiphon" principle of operation, the filling of the small insulated tank S with liquefied cryogenic gas at the same pressure and temperature as the storage tank 1.

[0014] When the level L1 indicates the presence of the liquid at the preset threshold, the control system commands the closing of the valves V1 and V2 which were previously open.

[0015] In order to transfer the liquefied gas from the

tank S to the vaporizer 2, the valve V3 is then opened, which brings the tank S to the same pressure as the vaporizer 2 and as the downstream usage station. Immediately afterwards the valve V4 is also opened. This causes the emptying of the liquefied gas contained in the tank S to the vaporizer, thanks to the simple difference in height between the tank S and the lower part of the vaporizer. Upon reaching the level threshold considered the minimum, the level signaling device L2 commands the closing of the valves V3 and V4.

[0016] The liquefied gas introduced into the vaporizer will evaporate, restoring the initial pressure conditions of the vaporizer, because the volume of the tank S will be calculated to contain a quantity of liquid gas corresponding to the quantity of gas comprised between the maximum and minimum pressure of the vaporizer.

[0017] As an alternative to such a system for controlling the gas fill volume in the vaporizer, a specific system can be used for measuring the quantity of gas dispensed to the bottles in the filling step. In fact, based on the volume of gas dispensed a control system will decide how many fillings/emptyings of the tank S are necessary to restore the pressure of the vaporizer.

[0018] Following the completion of the previous step, the valve V is opened which slowly introduces into the main tank 1 the pressure in the gaseous phase contained in the tank S, making it bubble through the liquid phase of the tank 1 or through an inner coil. This is done in order to lower the temperature of such gas and enable it to condense inside the storage tank 1 without bringing it, little by little, to a state of excess pressure. Upon reaching the same pressures in the main storage tank 1 and the tank S, the valve V is closed again.

[0019] At this point the cycle can be repeated, until the desired quantity of product to be transferred is reached.

[0020] The operating principle of the system in Figure 2 is the same, except that the condensation of the gaseous part at the end of the cycle occurs in the two tanks S1 and S2 outside the storage tank 1, so as to diminish any problems of excess pressure which could occur in the tank.

[0021] The liquefied cryogenic gas is kept at a low temperature (typically from -160 to -190°C depending on the type of gas) in the cryogenic tank 1 with typical storage pressures of normally just a few bar, similarly to the previous example.

[0022] With the system ready for operation, the vaporizer 2, which is connected to the downstream usage station, is normally kept at a pressure comprised between 250 and 300 bar, while all the valves are kept closed. With the withdrawal of gas downstream of the system, for example owing to the filling of bottles, there is naturally a fall in pressure in the vaporizer 2.

[0023] Upon reaching the preset minimum pressure threshold, the control system commands the opening of the valves V13, V1 and V3, which causes, thanks to the simple "thermosiphon" principle of operation, the filling of the small insulated tank S1 until the level L1, by indi-

cating the presence of the liquid at the preset threshold, commands the closing of the valves V13, V1 and V3 which were previously open.

[0024] In order to transfer the liquefied gas contained in the tank S1 to the vaporizer, the valve V2 is opened, which brings the tank S1 to the same pressure as the vaporizer 2 and immediately afterwards the valve V4 is also opened.

[0025] This causes the emptying of the liquefied gas to the vaporizer, thanks to the simple difference in height between the tank S1 and the base of the vaporizer. Upon reaching the level threshold considered the minimum, the level signaling device L2 commands the closing of the valves V2 and V4.

[0026] The liquefied gas introduced into the vaporizer will evaporate, restoring the initial pressure conditions of the vaporizer, because the volume of the tank S1 will be calculated to contain a quantity of liquid gas corresponding to the quantity of gas between the maximum and minimum pressure of the vaporizer.

[0027] As an alternative to such a system for controlling the fill volume, a specific system can be used for measuring the quantity of gas dispensed to the bottles to be filled. Based on the volume of gas dispensed, a control system will decide how many fillings/emptyings of the tanks S1 and S2 are necessary to restore the pressure of the vaporizer 2.

[0028] In order to accelerate the emptying of the tank S1, or when it is not possible to adhere to specific levels between the tank S1 and the vaporizer which enable its natural emptying, it is possible to force such operation in the following manner: after filling the tank S1 and closing the respective valves V13, V1 and V3, and after opening the valves V2 and V4 for the rebalancing of the pressure of the tank S1 with the vaporizer, the valve V2 is closed and the valve V10 is opened. Thanks to a simple principle of communicating vessels, the liquefied gas contained in the tank S1 flows toward the vaporizing coil 3 arranged behind the valve V10, which causes the vaporization of part of the liquefied gas. The vapor that is created ends up at the top of the tank S1 thus causing the forced expulsion of the liquid contained in S1 toward the vaporizer, through the valve V4 which is still open.

[0029] Upon reaching the minimum level of S1 the level sensor L2 interrupts the emptying by closing all the valves that were previously open.

[0030] Such system of forced emptying can also be applied to the system that was previously described in Figure 1.

[0031] The cycle, if necessary, proceeds by way of filling the tank S2, i.e. by opening the valves V13, V5 and V8, until the level L3 commands the closing of the three valves that were previously open.

[0032] Only at this point will the valve V9 be opened, which will transfer the gas under high pressure contained in the tank S1, which was previously emptied of the liquid part, by making it bubble slowly through a coil in the tank S2 containing liquefied gas and here, by cooling, much

of it will condense in the liquefied gas contained in S2. Upon reaching the same pressure, the valve V9 will be closed and the tank S2 will be emptied in the same way in which the tank S1 was emptied.

[0033] Simultaneously, the tank S1, after the transfer of much of its gas content to the tank S2, discharges the residual excess pressure in the main tank by opening the valve V1 and the valve V12, which will discharge the pressure remaining in S1 into the main storage tank by bubbling it in the liquid phase or through an inner coil in the main cryogenic tank. This is in order to lower the temperature of such residual gas and enable it to condense inside the storage tank thus preventing it from being brought, little by little, to a state of excess pressure. Upon reaching the equalization of the pressures in the main storage tank and the tank S1, the valves V1 and V12 are closed.

[0034] At this point the cycle can be repeated as necessary from the beginning, reversing the roles of the tanks S1 and S2 alternately.

[0035] Naturally, without prejudice to the general characteristics shown and described, and independently of the type of liquid treated, modifications or variations are not ruled out which, while still being comprised in the scope of the appended claims, may concern: the use of different means or systems for the transfer of the liquid and/or its expulsion after adequate raising of pressure and vaporization; the use of different materials or systems for the construction of the various vaporization tanks and accessories, and for adaptation to systems other than the one used for the purposes of example.

[0036] The disclosures in Italian Patent Application No. RA2012A000014 from which this application claims priority are incorporated herein by reference.

[0037] Where technical features mentioned in any claim are followed by reference signs, those reference signs have been included for the sole purpose of increasing the intelligibility of the claims and accordingly, such reference signs do not have any limiting effect on the interpretation of each element identified by way of example by such reference signs.

Claims

1. High and low pressure pumping systems for cryogenic or liquefied gases, said systems comprising at least one cryogenic tank (1) in which a liquefied cryogenic gas is stored at low pressure and at least one vaporizer (2) which is connected to a gas offtake region located downstream of the system, **characterized in that** they comprise: at least one insulated tank (S; S1) which is interposed between the cryogenic tank (1) and the vaporizer (2); valves (V1, V2, V; V1, V3, V13) for connecting said tank (S; S1) to the tank (1) and valves (V3, V4; V2, V4) for connecting said tank (S; S1) to the vaporizer (2).

2. The pumping systems according to claim 1, in which a vaporizing coil (3) is arranged behind a valve (V10) and is connected to the insulated tank (S; S1) in order to accelerate the emptying thereof by making the liquefied gas contained in the aforementioned tank flow into said coil.

3. The pumping systems according to claim 1, in which a tank (S2) is connected in series with the insulated tank (S; S1) and is further connected to the tank (1) and to the vaporizer (2) in order to render the transfer cycle of the cryogenic gas from (1) a (2) more stable.

4. A method of operation of high and low pressure pumping systems for cryogenic or liquefied gases according to claim 1, **characterized in that** it comprises the following steps:

- withdrawing gas from the vaporizer (2);
- upon reaching the preset minimum pressure threshold, opening the valves which are normally closed (V1 and V2) in order to fill the small insulated tank (S) with liquefied cryogenic gas at the same pressure and temperature as the storage tank (1);
- upon reaching the preset level (L1) closing the valves V1 and V2 which were previously open;
- opening the valve (V3), which brings the tank (S) to the same pressure as the vaporizer (2) and as the downstream storage;
- also opening the valve (V4) in order to empty the tank (S) of liquefied gas and transfer it to the vaporizer;
- upon reaching the threshold level considered minimum, closing the valves (V3 and V4);
- opening the valve (V) in order to slowly discharge the pressurized gas of the tank (S) into the main storage tank (1), in order to lower the temperature of said gas and allow it to condense inside the tank (1) without bringing it little by little to a state of excess pressure;
- closing the valve (V) again upon reaching the same pressures in the tank (1) and the tank (S);
- repeating the cycle from step 1 until the desired quantity of product to be transferred is reached.

5. The method of operation of high and low pressure pumping systems for cryogenic or liquefied gases according to one or more of claims 1-3, **characterized in that** it comprises the following steps:

- withdrawing gas from the vaporizer (2);
- upon reaching the preset minimum pressure threshold, opening the valves which are normally closed (V13, V1 and V3) in order to fill the insulated tank (S1) up to the preset level;
- upon reaching the level (L1) closing the valves (V13, V1 and V3) which were previously opened;

- opening the valve (V2), which brings the tank (S1) to the same pressure as the vaporizer (2) and as the downstream storage;
- also opening the valve (V4) in order to empty the tank (S) of liquefied gas and transfer it to the vaporizer; 5
- in order to accelerate the process, closing the valve (V2) and opening the valve (V10) in order to make the liquefied gas contained in the tank (S1) flow to the vaporizing coil (3) which is arranged behind the valve (V10), which causes the vaporization of part of the liquefied gas and thus causing the forced expulsion of the liquid contained in (S1) toward the vaporizer, through the valve (V4) which is still open; 10 15
- upon reaching the minimum level of (S1) interrupting the emptying by closing all the valves that were previously open;
- opening the valves (V13, V5 and V8) until the tank (S2) is filled; 20
- closing the valves (V13, V5 and V8);
- opening the valve (V9) in order to transfer the gas under high pressure contained in the tank (S1), which was previously emptied of the liquid part, to the tank (S2) containing liquefied gas; 25
- upon reaching the same pressure, closing the valve (V9) and proceeding to empty the tank (S2);
- opening the valve (V1) and the valve (V12) in order to finish discharging the residual excess pressure from the tank (S1) to the main tank (1); 30
- closing the valves (V1 and V12) again upon reaching the equalization of the pressures in the main storage tank (1) and the tank (S1).
- repeating the cycle from step 1 until the desired quantity of product to be transferred is reached, alternately inverting the tanks (S1 and S2). 35

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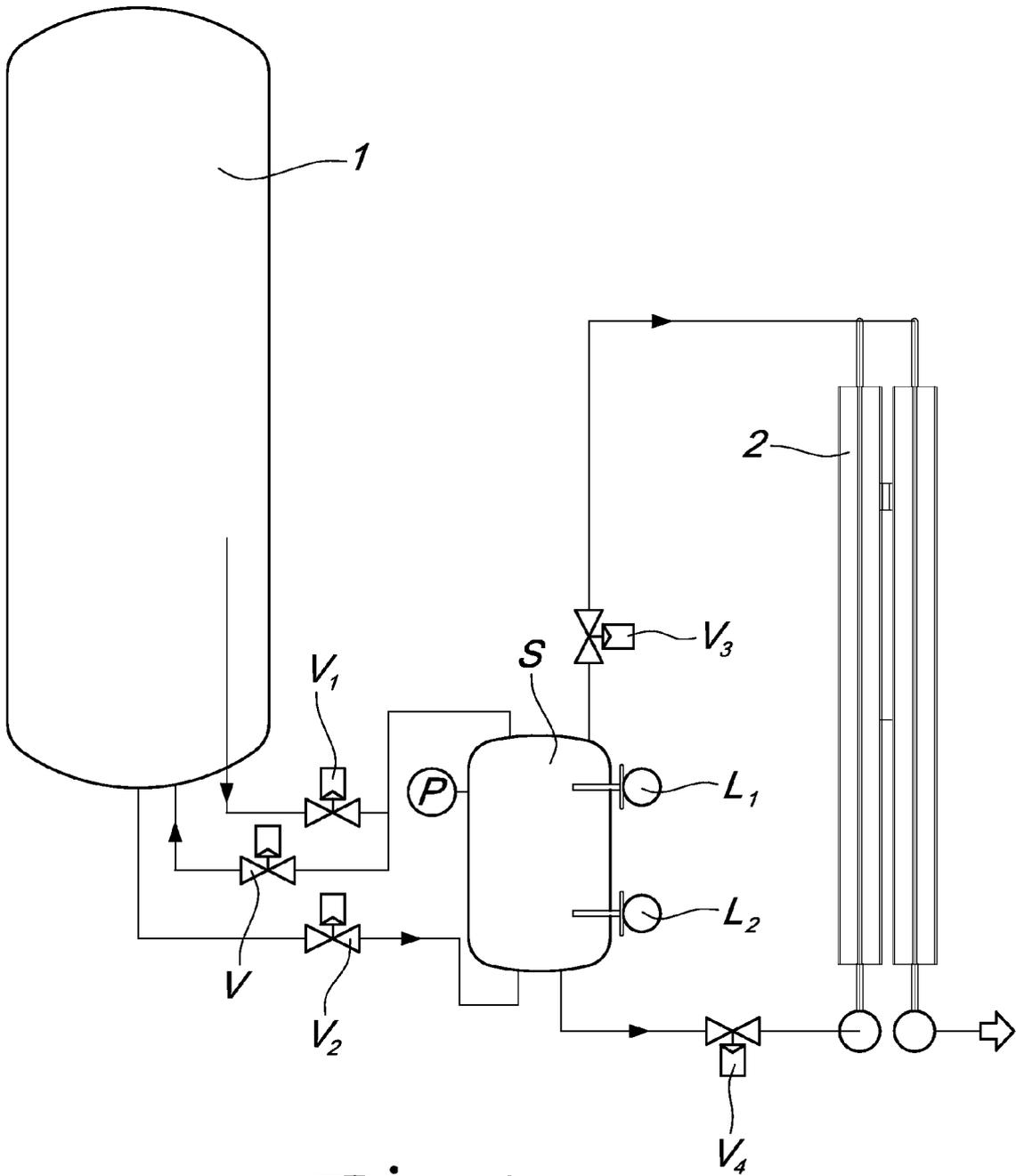


Fig. 1

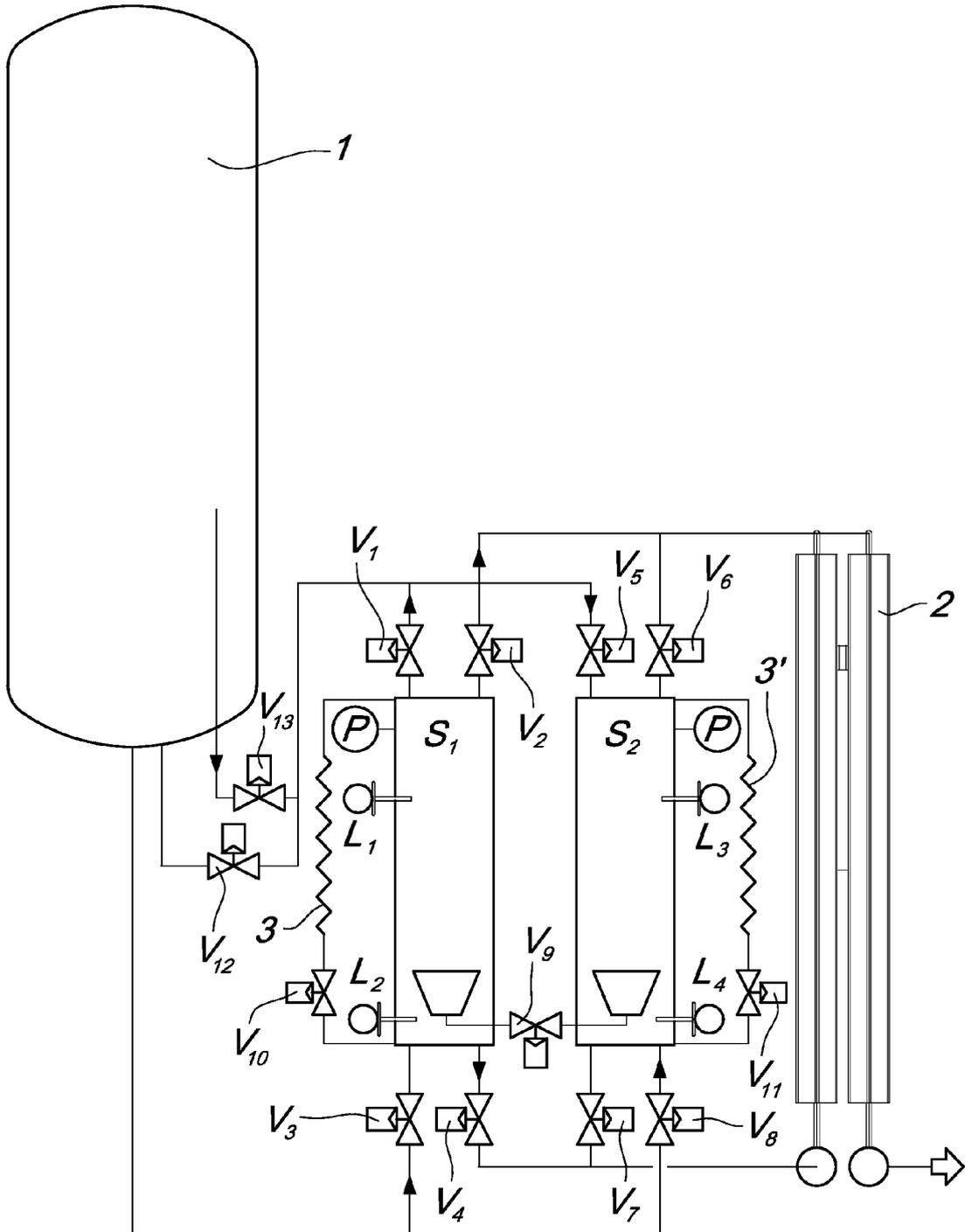


Fig. 2

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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