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(54) A CLEANING APPARATUS FOR CLEANING TEXTILE PRODUCTS, PROTECTIVE GEAR AND/OR EQUIPMENT

(57) A cleaning apparatus (100) for cleaning textile products, protective gear and/or equipment is provided. The apparatus comprises a container (110) for receiving said textile products, protective gear and/or equipment, and the container (110) is adapted to receive a compressed gas, this compressed gas being the cleaning fluid. The compressed gas is in gaseous, liquid or supercritical liquid state. The apparatus (100) further comprises a first and a second, mutually separated fluid system (200, 300), which first fluid system (200) comprises a first fluid conducting means (210) in the container (110) to heat the compressed gas in gaseous, liquid or supercritical liquid state in this container (110), the second fluid system (300) comprising a second fluid conducting means (310) in the container (110) to cool the compressed gas in gaseous, liquid or supercritical liquid state in the container (110).

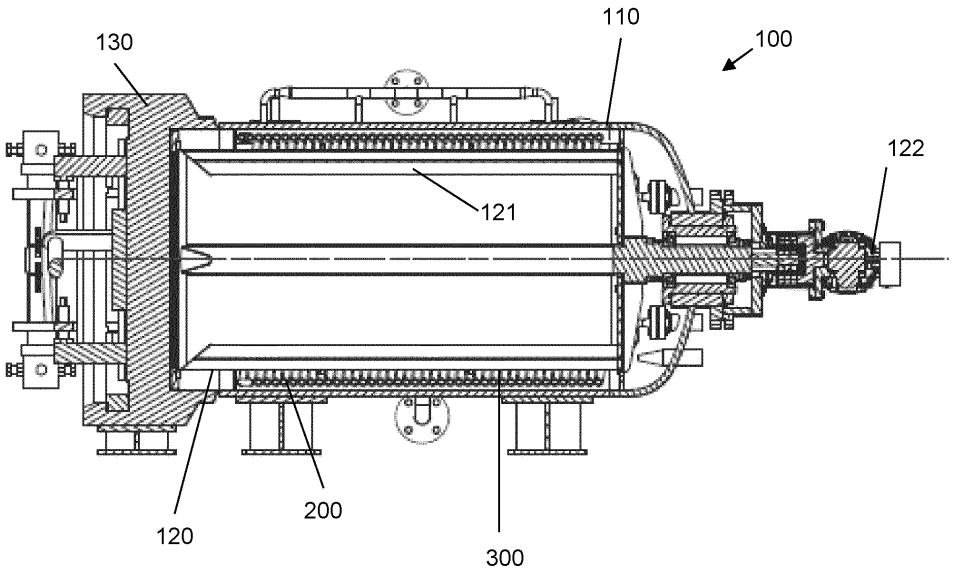

Fig. 2

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Description

Field of the Invention

[0001] The present invention generally relates to cleaning apparatuses for cleaning textile products, protective gear and/or equipment, and methods to clean textile products, protective gear and/or equipment.

Background of the Invention

[0002] Cleaning or decontaminating textile products is a task which has been performed since ages. In most applications, water and detergents are used to submerge the textile products in, while applying a mechanical action. Household washing machines are a very well-known example of such cleaning or decontaminating activity.

[0003] In other cleaning or decontamination processes, a solvent is used to dissolve the contamination on the textile products.

[0004] Lately, the idea of using liquified gasses to clean or decontaminate textile products has gained more interest again. The advantage is that the washing liquid, i.e. the compressed gasses, can be recuperated to a large extent, and is not to be thrown away or drained. In most processes, the gas CO2 is used, in compressed liquid or even supercritical liquid state, to clean the textile products. This is e.g. known from WO2021105501.

[0005] There is a continuous need to apparatuses for cleaning textile products, protective gear and/or equipment using such compressed liquid or even supercritical liquid state, which apparatuses are more easy to use, more performant during cleaning, less time consuming during use, and/or adapted to a higher cleaning performance.

Summary of the Invention

[0006] According to a first, independent aspect of the invention, a cleaning apparatus for cleaning textile products, protective gear and/or equipment is provided. The apparatus comprises a container for receiving said textile products, protective gear and/or equipment, and the container is adapted to receive a compressed gas, this compressed gas being the cleaning fluid. The compressed gas is in gaseous, liquid or supercritical liquid state. The apparatus further comprises a first and a second, mutually separated fluid system, which first fluid system comprises a first fluid conducting means in the container to heat the compressed gas in gaseous, liquid or supercritical liquid state in this container, the second fluid system comprising a second fluid conducting means in the container to cool the compressed gas in gaseous, liquid or supercritical liquid state in the container.

[0007] According to some embodiments, the apparatus may comprise a vessel in said container, said vessel being adapted to receive said textile products, protective gear and/or equipment.

[0008] According to some embodiments, each of said fluid conducting means may comprise a tubing having the shape of a helix positioned within said container.

[0009] A helix may also be referred to as coil. The helices may be left-hand or right hand helices.

[0010] Preferably the helices pass around said vessel, most preferably having their axes parallel or even coinciding with the axis of the vessel. This vessel may be a cylindrical drum. The helices are in that case preferably circular helices.

[0011] According to some embodiments, each tubing may comprise two mutually parallel and adjacent conduits.

[0012] For each tubing, two adjacent conduits to allow fluid to pass through the tube are provided. The ends of the conduits at one side of the tubing form the inlet and outlet of the tubing, the other ends of the two conduits are in fluid connection with each other, e.g. by means of a U-shaped tubular bridge fluidly connecting the two open ends to each other.

[0013] The double conduit tubing may be provided as a helix with two conduits parallel and adjacent one to the other.

[0014] According to some embodiments, the tubing of the first fluid conducting means and the tubing of the second fluid conducting means together may form a double helix.

[0015] Preferably the conduits, or as the case may be double conduits, of the two tubing are similar, i.e. having the same or a similar inner diameter, outer diameter and/or length. They may be provided from the same or a similar material, preferably a high thermal conductive material like such as steel.

[0016] According to some embodiments, the first fluid system may comprise a heat exchanger to heat fluid passing in said first fluid system.

[0017] The heat exchanger may be a tube/shell heat exchanger, a boiler or any other suitable means to have the temperature of a fluid, preferably a liquid, and referred to as heating fluid or liquid, to increase.

[0018] The heating fluid may be e.g. water or R744, i.e. CO2.

[0019] The temperature of the heating fluid may vary between e.g. 20°C and 90 °C. Preferably the temperature of the heating fluid may vary between e.g. 30°C and 90°C upon entering the heat exchanger, and between 20°C and 80°C°C upon leaving the heat exchanger.

[0020] According to some embodiments, the second fluid system may comprise a heat exchanger to cool fluid passing

in said first fluid system.

[0021] The heat exchanger may be a tube/shell heat exchanger, an air cooler or any other suitable means to have the temperature of a fluid, preferably a liquid, and referred to as cooling fluid or liquid, to decrease.

[0022] The cooling fluid may be e.g. water, brine, glucol, water with glycol or R744.

[0023] The temperature of the cooling fluid may vary between e.g. -12°C and 18 °C. Preferably the temperature of the cooling fluid may vary between e.g. -12°C and 18 °C upon entering the heat exchanger, and between -6°C and 18°C upon leaving the heat exchanger.

[0024] According to some embodiments, the first fluid system may comprise a fluid displacement means to displace fluid passing in said first fluid system, said second fluid system comprises a fluid displacement means to displace fluid passing in said second fluid system.

[0025] According to some embodiments, the apparatus may comprise a control means to control the fluid displacement means of the first and second fluid system.

[0026] An apparatus according to the invention has advantages. Because the heating and cooling means of the compressed gas in gaseous, liquid or supercritical liquid state in the container is fully separated, different fluids may be used for cooling and heating, and this without any risk to contaminate or cross-contaminate the fluids. The tubing and equipment used for the cooling and heating circuits may each be tuned to the needs of the cooling or heating system. Different tubing, pumps, valves, and control mechanisms may be used. There is no need for valved which are to be switched in order to allow either one of the two fluids pass, blocking the other fluid. The switch between cooling and heating can be made instantaneous, without the need to overcome the thermal inertia of the tubing in the container as is the case for a tubing used to conduct both the heating and cooling liquid. Switching between a cooling step and a heating step is made very easy and swift.

[0027] According to a second, independent aspect of the invention, a cleaning apparatus for cleaning textile products, protective gear and/or equipment is provided. The apparatus comprises a container adapted to receive a compressed gas being the cleaning fluid, said compressed gas being in gaseous, liquid or supercritical liquid state, and this apparatus comprises a fluid displacement means for displacing the cleaning fluid, hence the compressed gas, said fluid displacement means comprises at least a first and a second fluid displacing element, both adapted to displace a liquid and to compress a gaseous fluid, both fluid displacement elements comprising a fluid inlet adapted to receive fluid from the container, and a fluid outlet adapted to provide displaced or compressed fluid to a tubing system off stream the fluid displacement means. The fluid displacement means further comprises a fluid coupling between the outlet of the first displacement element and the inlet of the second displacement element, this fluid displacing element comprising a valve system to couple the outlet of the first displacement element to either the tubing system off stream the fluid displacement means or the inlet of the second displacement element.

[0028] As such the two displacement means may displace the compressed gas being in gaseous, liquid or supercritical liquid state in parallel from the container when pumping off the liquid. After the compressed gas in gaseous, liquid or supercritical liquid state being removed from the container, the remainder of the gas, no longer in liquid state, may have to be removed, compressed and pumped from the container to a storage, optionally after passing a condenser. This to degas the container. To displace and compress this gas in gaseous state, the gaseous fluid may be taken from the container and compressed in two stages. The second fluid displacement element may be provided with the outlet, hence the compressed gaseous fluid from the first fluid displacement element and may further compress the gaseous fluid to a higher pressure.

[0029] According to some embodiments, the apparatus may comprise a heat exchanger to cool the fluid between the outlet of the first fluid displacement element and the inlet of the second fluid displacement element when the fluid displacing element couples the outlet of the first displacement element to the inlet of the second displacement element.

[0030] This heat exchanger, which may be an air cooler or a tube and shell heat exchanger or any other suitable means, functions as an intercooler between the two stage compression of the gaseous fluid. As such the compression efficiency may be increased, while the temperature of the displaced gaseous fluid is kept within limits allowing the fluid to be handled in a fluid displacing element comprising materials which do not need to resist such increased temperatures as if the case without the intercooler were present.

[0031] According to some embodiments, the first fluid displacement element may be or may be part of a plunger displacement compressor.

[0032] The plunger displacement compressor may be a multi plunger displacement compressor. It may comprise pistons axially moving in a cylinder, to displace liquid fluid and to compress gaseous fluids. For a multi plunger displacement compressor, each of the plungers is part of a fluid displacement element. The chambers of the multi plunger displacement compressor in which the plungers move, may be fluidly connected by tubing and a valve system to couple the outlet of the first chamber, i.e. the chamber from the first fluid displacement element, to either the tubing system off stream the fluid displacement means or the inlet of a second chamber, i.e. the chamber from the second fluid displacement element.

[0033] According to some embodiments, the fluid displacement means may comprise at least a third fluid displacing

element, adapted to displace a liquid and to compress a gaseous fluid, said third fluid displacement elements comprising a fluid inlet adapted to receive fluid from the container, and a fluid outlet adapted to provide displaced or compressed fluid to a tubing system off stream the fluid displacement means, the fluid displacement means further comprises a fluid coupling between the outlet of the third displacement element and the inlet of the second displacement element, the fluid displacing element comprising a valve system to couple the outlet of the third displacement element to either the tubing system off stream the fluid displacement means or the inlet of the second displacement element.

[0034] According to some embodiments, the third fluid displacing element may be adapted to displace fluid in parallel to the fluid displacing According to some embodiments, the intake pressure of first fluid displacing element may be in the range of 1.5 bara to 65 bara. The output pressure of first fluid displacing element may be in the range of 30 bara to 50 bara. According to some embodiments, the intake pressure of second fluid displacing element may be in the range of 1.5 bara to 65 bara. The output pressure of second fluid displacing element may be in the range of 30 bara to 65bara.

[0035] Optionally, the fluid displacement means comprises one or more than one additional fluid displacing elements, which are fluidly coupled to the outlet of the second fluid displacing element. As such a multiple stage compressing may be provided to the gaseous fluid to be displaced. Possibly between some, or even between each comprising stage, an intercooling may be executed by a heat exchanging, hence cooling means. optionally some of the more than one additional fluid displacing elements may be coupled in parallel.

[0036] The cleaning apparatus of the second aspect of the invention, may comprise one, more than one or even all features of a cleaning apparatus of the first aspect of the invention

[0037] The cleaning apparatus according to any one of the first and/or second aspect of the invention, may further comprise an evaporation means.

[0038] The compressed gas being in gaseous, liquid or supercritical liquid state, after cleaning a textile products, protective gear and/or equipment comprises contaminants and/or detergents, optionally also some water. This compressed gas being in gaseous, liquid or supercritical liquid state, either during the cleaning steps performed in the container, or after completion of a cleaning step, may be pumped to an evaporator. The compressed gas in gaseous, liquid or supercritical liquid state is decompressed and evaporated by heating the compressed gas in gaseous, liquid or supercritical liquid state. The contaminants and/or detergents, optionally also some water may remain as a liquid in the evaporator, while the gas is drawn off and possibly recuperated, compressed, liquified and stored for a next cleaning step in the container.

[0039] According to some embodiments, a cleaning apparatus for cleaning textile products, protective gear and/or equipment, said apparatus comprises a container adapted to receive a compressed gas, said compressed gas being in gaseous, liquid or supercritical liquid state, said apparatus comprises a fluid displacement means, said fluid displacement means comprises at least a first and a second fluid displacing element, both adapted to displace a liquid and to compress a gaseous fluid, both fluid displacement elements comprising a fluid inlet adapted to receive fluid from the container, and a fluid outlet adapted to provide displaced or compressed fluid to a tubing system off stream the fluid displacement means, the fluid displacement means further comprises a fluid coupling between the outlet of the first displacement element and the inlet of the second displacement element, the fluid displacing element comprising a valve system to couple the outlet of the first displacement element to either the tubing system off stream the fluid displacement means or the inlet of the second displacement element. This apparatus further comprises a first and a second, mutually separated fluid system, the first fluid system comprising a first fluid conducting means in said container to heat the compressed gas in gaseous, liquid or supercritical liquid state in said container, and the second fluid system comprises a second fluid conducting means in said container to cool the compressed gas in gaseous, liquid or supercritical liquid state in said container.

[0040] Hence it is clear that the cleaning apparatus for cleaning textile products, protective gear and/or equipment according to the second aspect of the invention may comprise any feature as set out for the cleaning apparatus for cleaning textile products, protective gear and/or equipment according to the first aspect of the invention. According to a third, independent aspect of the invention, a cleaning apparatus for cleaning textile products, protective gear and/or equipment is provided. The apparatus comprises a container adapted to receive a compressed gas, which compressed gas is in gaseous, liquid or supercritical liquid state. The apparatus comprises a fluid displacement means, said fluid displacement means is adapted to displace said compressed gas being in gaseous, liquid or supercritical liquid state to an evaporator. The evaporator comprises a tube/shell heat exchanger, the compressed gas being in gaseous, liquid or supercritical liquid state is provided to the shell-side of the tube/shell heat exchanger.

[0041] According to some embodiments, tube/shell heat exchanger may comprise a tube-shaped drum in which the tubes of the tube/shell heat exchanger are present, the axis of the tube-shaped drum is oriented non-parallel to the horizontal.

[0042] According to some embodiments, the angle between the axis of the tube-shaped drum and the horizontal may be in the range of 0 to 5°.

[0043] Hence the evaporator is preferably slightly inclined to the horizontal.

[0044] According to some embodiments, a first discharge outlet may be provided for discharging the residue after

evaporation of the compressed gas being in gaseous, liquid or supercritical liquid state, said first discharge outlet is provided at the lower side of the tube-shaped drum.

[0045] According to some embodiments, the tubes of the tube/shell heat exchanger may be present in the lower half of the tube-shaped drum.

[0046] As such a significantly large open volume is created above the tubes. The evaporated gas may reside, liquid particles being dragged by the evaporating gas may fall out of the gaseous phase.

[0047] According to some embodiments, the tube-shaped drum may comprise a second discharge outlet for discharging the evaporated gas.

[0048] According to some embodiments, the second discharge outlet may be provided at the upper side of the tube-shaped drum.

[0049] According to some embodiments, the second discharge outlet for discharging the evaporated gas may be provided with a demising means to trap liquid particles being dragged by the evaporated gas.

[0050] As heating medium in the evaporator, water or R744 may be used. The pressure in the evaporator may by up to 100bara and may be up to 50°C

[0051] The cleaning apparatus according to any one of the first, second or third aspect of the invention, may be an apparatus for cleaning or decontaminating textile products, protective gear and/or equipment on industrial scale. Such apparatus typically may have a vessel in which 10 kg or more contaminated textile products, protective gear and/or equipment can be decontaminated during one process, e.g. up to 25kg or even up to 75 kg.

[0052] The cleaning apparatus according to any one of the first, second or third aspect of the invention, may be an apparatus for household use, cleaning or decontaminating textile products, protective gear and/or equipment on smaller scale. Such apparatus typically may have a vessel in which up to 10 kg contaminated textile products, protective gear and/or equipment can be decontaminated during one process, e.g. 4kg, 5kg, 6kg, 7kg or 8kg.

[0053] According to some embodiments, the cleaning apparatus for cleaning textile products, protective gear and/or equipment comprising a container for receiving said textile products, protective gear and/or equipment, the container being adapted to receive a compressed gas, being a compressed gas in gaseous, liquid or supercritical liquid state. This apparatus comprises a first and a second, mutually separated fluid system, the first fluid system comprising a first fluid conducting means in said container to heat the compressed gas in gaseous, liquid or supercritical liquid state in said container, and the second fluid system comprises a second fluid conducting means in said container to cool the compressed gas in gaseous, liquid or supercritical liquid state in said container. This apparatus comprises further a fluid displacement means, the fluid displacement means is adapted to displace the compressed gas being in gaseous, liquid or supercritical liquid state to an evaporator, wherein said evaporator comprises a tube/shell heat exchanger, the compressed gas being in gaseous, liquid or supercritical liquid state is provided to the shell-side of the tube/shell heat exchanger.

[0054] According to some embodiments, a cleaning apparatus for cleaning textile products, protective gear and/or equipment is provided, the apparatus comprises a container adapted to receive a compressed gas, said compressed gas being in gaseous, liquid or supercritical liquid state, said apparatus comprises a fluid displacement means, said fluid displacement means comprises at least a first and a second fluid displacing element, both adapted to displace a liquid and to compress a gaseous fluid, both fluid displacement elements comprising a fluid inlet adapted to receive fluid from the container, and a fluid outlet adapted to provide displaced or compressed fluid to a tubing system off stream the fluid displacement means, the fluid displacement means further comprises a fluid coupling between the outlet of the first displacement element and the inlet of the second displacement element, the fluid displacing element comprising a valve system to couple the outlet of the first displacement element to either the tubing system off stream the fluid displacement means or the inlet of the second displacement element.. This fluid displacement means is adapted to displace the compressed gas being in gaseous, liquid or supercritical liquid state to an evaporator, wherein said evaporator comprises a tube/shell heat exchanger, the compressed gas being in gaseous, liquid or supercritical liquid state is provided to the shell-side of the tube/shell heat exchanger.

[0055] According to some embodiments, a cleaning apparatus for cleaning textile products, protective gear and/or equipment, said apparatus comprises a container adapted to receive a compressed gas, said compressed gas being in gaseous, liquid or supercritical liquid state, said apparatus comprises a fluid displacement means, said fluid displacement means comprises at least a first and a second fluid displacing element, both adapted to displace a liquid and to compress a gaseous fluid, both fluid displacement elements comprising a fluid inlet adapted to receive fluid from the container, and a fluid outlet adapted to provide displaced or compressed fluid to a tubing system off stream the fluid displacement means, the fluid displacement means further comprises a fluid coupling between the outlet of the first displacement element and the inlet of the second displacement element, the fluid displacing element comprising a valve system to couple the outlet of the first displacement element to either the tubing system off stream the fluid displacement means or the inlet of the second displacement element. This apparatus further comprises a first and a second, mutually separated fluid system, the first fluid system comprising a first fluid conducting means in said container to heat the compressed gas in gaseous, liquid or supercritical liquid state in said container, and the second fluid system comprises

a second fluid conducting means in said container to cool the compressed gas in gaseous, liquid or supercritical liquid state in said container. The fluid displacement means is adapted to displace the compressed gas being in gaseous, liquid or supercritical liquid state to an evaporator, wherein said evaporator comprises a tube/shell heat exchanger, the compressed gas being in gaseous, liquid or supercritical liquid state is provided to the shell-side of the tube/shell heat exchanger.

[0056] Hence it is clear that the cleaning apparatus for cleaning textile products, protective gear and/or equipment according to the first aspect of the invention may comprise any feature as set out for the cleaning apparatus for cleaning textile products, protective gear and/or equipment according to the second aspect of the invention. It is clear that the cleaning apparatus for cleaning textile products, protective gear and/or equipment according to the second aspect of the invention may comprise any feature as set out for the cleaning apparatus for cleaning textile products, protective gear and/or equipment according to the third aspect of the invention. It is clear that the cleaning apparatus for cleaning textile products, protective gear and/or equipment according to the first aspect of the invention may comprise any feature as set out for the cleaning apparatus for cleaning textile products, protective gear and/or equipment according to the third aspect of the invention.

[0057] According to a fourth aspect of the invention, the apparatuses according to any of the first, second and/or third aspect of the invention, is used to decontaminate textile products, protective gear and/or equipment.

[0058] In the context of this method to decontaminate, i.e. clean, textile products, the term textile product is to be understood as a garments a piece of clothing or any Personal Equipment (such as helmets and boots), such as but not limited to technical garments and clothing, medical or surgical garments and clothing, protective garments and clothing, workwear, firemen garments and clothing, trousers, vests, t-shirts, skirts, pants, gloves, scaffolds, socks, sweaters, dresses, hoodies, shorts, coats, jeans, suits, polo shirts, caps, hats, leather products, boots, helmets, face shields, goggles, gowns, head covers, masks, respirators, shoe covers, ballistic vests, fall protection systems, chaps and alike. Protective gear and/or equipment are textile or other products, like Personal Equipment, used to protect a human or animal to hazards, like cold or increased temperatures, fire, stabs of knives or sharp objects, bacterial or chemical hazards, bullets, impacts, and many more.

[0059] According to some embodiments, nonpolar gasses are used to decontaminate textile products, protective gear and/or equipment, the nonpolar gas being brought to a pressure and temperature such it is present in gaseous, liquid or supercritical state.

[0060] Though several nonpolar gasses are useful, like He, Ne, Ar, Kr, Xe, H_2, D_2, N_2, O_2, CH_4, C_2H_4, C_2H_6, CCl_4, CF_4, SF_6 and CO_2, and mixtures thereof, the most useful one is CO_2. He, Ne, Ar, Kr, Xe, H_2, D_2, may be considered not economic for the use as cleaning gasses. CH_4, C_2H_4, C_2H_6 may be too dangerous seen their flammability. Freon (CF_4) and SF_6, as well as CCl_4 are considered too ecologically unfriendly, hence unacceptable in practice. N_2 and O_2 have to be cooled too deep in order to be liquid, hence not practical in use. Detergents, such as amphiphilic substances, may be added to the compressed gas in gaseous, liquid or supercritical liquid state.

[0061] Hence according to this fourth aspect of the invention, the apparatus according to the first, second and/or third aspect of the invention is used for cleaning technical garments and clothing, medical or surgical garments and clothing, protective garments and clothing, workwear, firemen garments.

[0062] According to a fifth aspect of the invention, a method to clean technical garments and clothing, medical or surgical garments and clothing, protective garments and clothing, workwear, firemen garments is provided, using an apparatus according to the first, second or third aspect of the invention to clean said technical garments and clothing, medical or surgical garments and clothing, protective garments and clothing, workwear, firemen garments. The apparatus according to the first, second and/or third aspect of the invention may be used for cleaning one or more textile products, protective gear and/or equipment. One product may be cleaned individually, but preferably a number of textile products may be cleaned simultaneously.

[0063] It is understood that the features relating and described in relation to the first aspect of the invention, may be combined with the features of the second and/or third aspect of the invention. It is also understood that the features relating and described in relation to the second aspect of the invention, may be combined with the features of the first and/or third aspect of the invention. Similarly, the features relating and described in relation to the third aspect of the invention, may be combined with the features of the first and/or second aspect of the invention.

Brief Description of the Drawings

[0064]

Fig. 1 illustrates schematically a container of a cleaning apparatus according to the invention.

Fig. 2 illustrates schematically a cross section according to the plane AA' of the container of figure 1.

Fig. 3 illustrates schematically a front view of the container of figure 1.

Fig. 4, 5, 6 and 7 illustrate schematically the first and second fluid conducting means being part of the cleaning apparatus according to the invention.

Fig. 8A and 8B illustrate schematically the flow scheme of a cleaning apparatus according to the invention.

Fig. 9 to 19 illustrate schematically how the fluid flows in the flow scheme of figure 8B, when a given phase in the cleaning process is active.

[0065] In the different figures, the same reference signs refer to the same or a similar feature or element.

Detailed Description of Embodiment(s)

[0066] A cleaning apparatus 100 for cleaning textile products, protective gear and/or equipment is shown schematically in figures 1 to 3. The apparatus 100 comprises a container 110 for receiving the product to be cleaned. The container can receive a compressed gas, e.g. CO2 in liquid or supercritical liquid state. This compressed gas is the cleaning fluid. A first separated fluid system 200 is provided in the container 110, this first fluid system comprising a first fluid conducting means 210, and is provided to conduct a heating fluid, like water, e.g. demiwater, in the first fluid conducting means 210, thereby being able to heat the compressed gas, in the container.

[0067] A second separated fluid system 300 is provided in the container 110, this first fluid system comprising a second fluid conducting means 310, and is provided to conduct a cooling fluid, like brine or glycol, in the second fluid conducting means 310, thereby being able to heat the compressed gas, in the container. The first and second fluid system are completely separate one to the other. This means there is no device provided, which enable to provide the cooling fluid flowing to, and have the cooling liquid flowing in have the first fluid conducting means 210, nor is there a device provided, which enable to provide the heating fluid flowing to, and have the heating liquid flowing in the second fluid conducting means 310.

[0068] Further, a vessel 120, such as a perforated drum, is provided in the container 110, which is adapted to receive and carry the product to be cleaned during the cleaning process. This vessel is rotatably mounted in the container. A closing means, e.g. a door 130 is provided to open and close the container 110, hence the vessel 120, in order to allow the user to put the product to be cleaned in, and to take the cleaned product out of the vessel 120. The door is constructed so the closed door can be kept closed firmly when the container is provided with the cleaning fluid e.g. CO2 in liquid or supercritical liquid state. At the inner side of the vessel, fins 121 may be provided to agitate the product to be cleaned, as well as the compressed gas, being the cleaning fluid, during the cleaning process. The rotation of the vessel is driven by a motor, usually an electromotor 122, and a magnetic coupling.

[0069] Each of the fluid conducting means 210 and 310 comprises a tubing having the shape of a helix being positioned within said container. Each tubing comprises two mutually parallel and adjacent conduits, and these two mutually parallel and adjacent conduits together form a double helix. This is best visible in the figures 4 to 7. The vessel 120 is coaxially mounted with this double helix, where the distance between the outer side of the vessel 120 and the inner side of the double helix is kept to a minimum. As such the cooling and heating fluid can be provided near the vessel and can be heat or cool the vessel and the cleaning fluid efficient.

[0070] The tubing may be provided from stainless steel tubes. The tubes of the first fluid conducting means 210 are connected to a heat exchanger to heat the heating fluid passing in this first fluid system. A fluid displacement means, comprising a pump, an appropriate valve system and alike is provided to enable the heating fluid to pass through the tubing when required. Similarly, the tubes of the second fluid conducting means 310 are connected to a heat exchanger to cool the cooling fluid passing in this second fluid system. Another fluid displacement means, comprising a pump and an appropriate valve system and alike is provided to enable the cooling fluid to pass through the tubing when required. The pump, valves and alike are controlled by a central controlling unit, which central controlling unit will control the functioning of the whole apparatus 100, including all fluid paths and fluid streams.

[0071] The provision of two totally independent and separated fluid system 200 and 300 has the advantage that different fluids can be used for heating and cooling the cleaning fluid in the vessel, and that a switch between cooling and heating can be made instantaneously. No time is lost to have a fluid cooled or heated, when this very same fluid is to switch between a cooling step and a heating step in the cleaning process. As such a very efficient cleaning process can be provided, with a reduction of the time needed to perform a cleaning process. By the provision of two separate and mutually independent fluid systems, the selection of the cooling and heating fluid can be made in function of the cooling and heating operation and performance needed. As such no compromise or choice is to be made as far as the cooling and heating performance of the fluid used to both cool and heat.

[0072] Further to the means to have the cooling and heating fluid circulating in the fluid systems 200 and 300, the

apparatus 100 comprises a fluid system to have the compressed gas, functioning as cleaning fluid, flowing and being displaces in the apparatus. Hence the apparatus 100 comprises a fluid displacement means 400. This fluid displacement means 400 comprises a quite complex system of tubing system 401, valves and other equipment, the schematic flow scheme being shown in figure 8A. Figure 8B shows the relevant possible flow paths to illustrate the process flow as described hereinafter. Figures 9 to 19 show schematically the paths the fluids are flowing during a given step of a cleaning process and refer to the corresponding tubing in figure 8A and 8B.

[0073] The apparatus 100 comprises, next to the container 110, at least a storage tank 500 and an evaporator 600. The storage tank 500 stores cleaning fluid, e.g. liquefied C02 gas. The evaporator 600 is used to evaporate cleaning fluid which comes from the container 110, and which cleaning fluid may be loaded with contamination. In the evaporator 600, also referred to as boiler, the cleaning fluid is decompressed, causing the contamination to stay in the residue at the bottom of the evaporator 600, cleaned cleaning fluid, in gaseous form, leaving the evaporator 600 at the top of the evaporator.

[0074] In the figures 9 to 19, the inflow point 211 of the heating fluid of the first fluid systems 200 is shown via which heated heating fluid enters the apparatus 100. The outflow point 212 via which used, hence cooled heating fluid is leaving the apparatus 100 is indicated as well. These two points are connected to the corresponding fluid displacement means. As is shown in figures 8 to 19, the inflow and outflow points 211 and 212 are also connected to the tube side of the tube/shell heat exchanger 601 in the evaporator 600. Appropriate controllable valves Vh1, Vh2 and Vh3 are provided to allow the control of heating fluid passing the tubes of the first fluid system 200.

[0075] In a similar way, the inflow point 311 of the cooling fluid of the first fluid systems 300 is shown via which cold cooling fluid enters the apparatus 100. The outflow point 312 via which used, hence heated cooling fluid is leaving the apparatus 100 is indicated as well. These two points are connected to the corresponding fluid displacement means. As is shown in figures 8 to 19, the inflow and outflow points 311 and 312 are also connected coolers and/or condensers 701, 702, 703 and 704, where the cooling fluid will be used to cool or to condense fluid passing through the coolers and/or condensers. Appropriate controllable valves Vc1, Vc2, Vc3, Vc4, Vc5, Vc6 and Vc7 are provided to allow the control of cooling fluid passing the tubes of the second fluid system 300, and to allow cooling of the first fluid displacing element 410 and a second fluid displacement element 420.

[0076] During the cleaning process, cleaning fluid, in liquid of gaseous form, is circulated and displaced by means of these first and second fluid displacing elements 410 and 420. These first and second fluid displacing elements 410 and 420 may as well be used as compressors compressing gaseous fluid. These two fluid displacement elements 410 and 420 may be coupled in parallel, to increase the capacity of gaseous or liquid fluid being displaced, or may be coupled in series, to increase the pressure of the gaseous fluid being compressed.

[0077] In the figures 9 to 19, various fluid paths are shown which are enabled and used during a cleaning process. The settings (open "O"/closed "C") of the various valves V1 to V20, Vc1 to Vc7, Vh1 to Vh3, Va1 and Va2, and Vw1 and Vw2 during the different phases used during the cleaning process, are set out in table I. The valves referred to as V## are adjustable valves via which cleaning fluid passes in opened condition. The valves referred to as Vc# are adjustable valves via which cooling fluid passes in opened condition. The valves referred to as Vh# are adjustable valves via which heating fluid passes in opened condition. The valves referred to as Vw# are adjustable valves via which purging water passes in opened condition, and the valves referred to as Va# are adjustable valves via which evacuated air passes in opened condition. Point 501 and 502 refer to charging points for the cleaning fluid, like CO2.Point 801 is an outlet point for waste water, loaded with contamination cleaned from the products to be cleaned, to be discharged. Point 802 is an inlet point for water, used to mix with the contamination cleaned from the products to be cleaned prior to discharging. Point 901 is an outlet point for air, taken out of the container 110, to be discharged. Points 902 are inlet points for various additives to be mixed in the cleaning fluid, prior or during the cleaning process.

Table I

valve/phase	Ph I	Ph II	Ph III	Ph IV	pH V	Ph VI	PHVII	pH VIII	Ph IX	Ph X	pH XI
figure	9	10	11	12	13	14	15	16	17	18	19
V1	C	C	O	C	C	C	C	C	C	C	C
V2	C	C	C	O	C	O	C	C	C	C	C
V3	C	C	C	C	C	C	C	C	C	C	C
V4	C	O	O	C	C	C	O	C	C	C	C
V5	C	O	C	C	C	C	C	C	O	C	C
V6	C	O	O or C	C	O or C	O	C	O	O	O or C	O or C

(continued)

valve/phase	Ph I	Ph II	Ph III	Ph IV	pH V	Ph VI	PHVII	pH VIII	Ph IX	Ph X	pH XI
V7	C	O	C	C	C	O	C	O	C	O or C	O or C
V8	C	O	O	C	C	C	O	C	C	C	C
V9	C	O	O	C	C	C	O	C	C	C	C
V10	C	O	C	C	C	O	C	O	C	O	O
V11	C	C	C	C	C	C	C	O	C	O	O
V12	C	C	C	C	C	C	C	C	O	C	C
V13	C	C	C	C	C	C	C	O	O	O	O
V14	C	C	C	O	C	O	C	O	O	O	C
V15	C	C	C	C	C	C	C	C	C	C	O
V16	C	o or C	O or C	O	C	C	C	O	C	O	O
V17	C	C	C	O	C	C	C	C	C	C	C
V18	C	C	C	O	C	O	C	O	O	O	C
V19	C	C	C	C	C	C	C	C	C	C	C
V20	C	C	C	C	C	O	C	O	O	O	O
Va1	O	C	C	C	C	C	C	C	C	C	C
Va2	O	C	C	C	C	C	C	C	C	C	C
Vc1	C	C	C	C	C	C	C	C	C	C	C
Vc2	C	C	C	C	C	C	O	C	C	C	C
Vc3	C	C	C	C	C	O	C	O	O	O	C
Vc4	C	C	C	C	C	C	C	O	C	O	O
Vc5	C	C	C	C	C	O	C	O	O	O	O
Vc6	C	C	C	C	C	O	C	O	O	O	O
Vc7	C	C	C	C	O <-> C	C	O	C	C	C	C
Vh1	C	C	C	C	C	C	C	C	C	C	C
Vh2	C	C	C	C	O <-> C	C	C	C	C	C	C
Vh3	C	C	C	C	C	O	C	C	C	O	O
Vw1	C	C	C	C	C	C	C	C	C	C	C
Vw2	C	C	C	C	C	C	C	C	C	C	C

[0078] At start, the cleaning apparatus is in idle situation. The container can be loaded and the filter can be changed if necessary. The container is at atmospheric conditions, the valves V3 and V6 are open, while all other valves are closed. As such atmospheric conditions, like pressure, can be obtained in the container 110 and over the filter 520. As shown in figure 9, at the start of a cleaning process, using a pre-set number of washing cycles and alike, and predefined temperatures and pressures, an air extraction phase (Ph I) is executed. The container 110 is closed and is brought to a vacuum, about -0.9barg, by taking out the air in the container 110. The vales Va1 and Va2 are in open position. The vacuum pump Pa draws the air from the container and pumps this to the outlet point 901. Possibly, the valve V6 is also kept open, to bring the filter under this relative vacuum.

[0079] Once this air extraction phase is completed, the valve settings are changed and brought in a position to allow the fluid path as shown in figure 10. During this pressurisation phase (Ph II), gaseous cleaning fluid (like gaseous CO2) is conducted from the storage tank 500, to the evaporator 600 and further to the container 100 being under relative vacuum. The pressure in the container 110 and the evaporator 600 equilibrates with the pressure of the storage tank 500, being about 75 barg. Also here, the valve V6 may be kept open to have the filter being brought under pressure.

[0080] In case the amount of cleaning fluid is not sufficient, cleaning fluid from an external source is fed to the apparatus 100 via charging point 501. The fluid paths for use during this intermediate, optional phase (Ph III), are shown in figure 11. In order to avoid unbalanced pressures, this external cleaning fluid, in gaseous form, is conducted via the container 110 also to the storage tank 500. Also here, the valve V6 may be kept open to have the filter being brought under pressure.

[0081] At this moment in the cleaning process, the container 110 and the evaporator 600 are filled with gaseous fluid. In the next phase, the liquid filling phase (Ph IV), the fluid paths are enabled as shown in figure 12. By opening the valves as set out in table I, and by activating the first and second fluid displacing elements 410 and 420, working in parallel, for pumping liquid cleaning fluid from the storage tank 500 to the container 110, the container gets filled with liquid cleaning fluid up to a present level. as is shown in figure 12, cooling fluid may be used to cool the liquid fluid streams prior to the first and second fluid displacing elements 410 and 420, and to cool the first and second fluid displacing elements 410 and 420 itself. Prior to entering the container 110, additives may be added to the liquid cleaning fluid by activating one or more of the pumps Pad1 to Pad4. It is clear that more lines to add additives may be provided. During filling, the vessel may be rotated.

[0082] After this liquid filling phase, the container is ready to clean the products to be cleaned, present in its rotatable vessel. Two phases may be applied and/or repeated. In a first cleaning phase (Ph V), shown in figure 13, the pressure in the container 110 is altered, increased or decreased, or repetitively increased and decreased by providing heating fluid through the first fluid systems 200 or providing cooling fluid through the second fluid systems 300. The valves Vh2 and Vc5 are opening and closing in a controlled way to obtain pressure variations in the container 110. During this operation, the valve V6 may be kept open to have the altered pressure present over the filter.

[0083] In a second cleaning phase (Ph VI), shown in figure 14, the cleaning fluid is circulated, while contamination is taken out of the cleaning fluid in the evaporator 600. Contaminated cleaning fluid is conducted through V6 and filter 520, filtering out solid particles, and valve V7, to the evaporator, where the liquid fluid is evaporated by energy provided by the heating fluid from the first fluid system 200.

[0084] The gaseous cleaning fluid is drawn of from the evaporator 600 by activating the first and second fluid displacing elements 410 and 420 working as pumps and in parallel. The gaseous cleaning fluid is condensed in the heat exchangers 702 and 703, and the first and second fluid displacing elements 410 and 420 are cooled, by cooling fluid provided by the second fluid system 300. The liquid cleaning fluid is returned to the container 110. Again, additives may be added to the liquid cleaning fluid by activating one or more of the pumps Pad1 to Pad4. Typically the vessel is rotated during this step, possibly using alternating directions.

[0085] Once the cleaning of the products in the container 110 is terminated, the apparatus 100 needs to be brought in a situation where the cleaned products can be taken out of the container 110 safely. The container 110 is at a pressure which may be higher as the pressure in the storage tank 500 and filled with cleaning fluid in liquid state. Hence the liquid must be removed, and the pressure in the container must be brought to ambient as well.

[0086] During the decompression phase (Ph VII) as shown in figure 15, cooling fluid provided by the second fluid system 300 is used to bring down the pressure in the container 110, e.g. when the pressure is above 75 barg. The valves as shown in table I are opened, and the cleaning fluid in gaseous state flows to the storage tank 500, where the incoming cleaning fluid is cooled and optionally condensed by heat exchanger 701. This phase is executed until the pressure of the container 110 and the storage tank 500 are in balance.

[0087] After this decompression phase, the liquid cleaning fluid in the container 110 must be evacuated. Here first a liquid extraction under gravity (phase Ph VIII) may be used, as shown in figure 16. Valves V6 and valve V7 are opened, so the liquid may balance between the container 110 and the evaporator 600 under gravity, i.e. by allowing the two tanks to equilibrate like communicating vessels. Meanwhile the gaseous cleaning fluid is drawn of from the evaporator 600 by activating the first and second fluid displacing elements 410 and 420 working as compressors and in parallel. The gaseous cleaning fluid is cooled in the heat exchangers 702 and 703, and the first and second fluid displacing elements 410 and 420 are cooled, by cooling fluid provided by the second fluid system 300. The gaseous cleaning liquid is condensed in heat exchanger 704, and this liquid cleaning fluid is returned to the storage tank 500.

[0088] Alternatively or at some point in time, the fluid path is altered to the one shown in figure 17 (phase Ph IX). The remaining liquid cleaning fluid is pumped by the first and second fluid displacing elements 410 and 420 to the evaporator, where it is temporarily stored. The liquid cleaning fluid is cooled in the heat exchangers 702 and 703, and the first and second fluid displacing elements 410 and 420 are cooled, by cooling fluid provided by the second fluid system 300.

[0089] At this moment in the cleaning process, the remainder or even all the liquid cleaning fluid is stored int eh evaporator 600. Now a gas extraction phase is activated, first with the fluid paths as shown in figure 18. During this gas extraction phase part I (Ph X), the evaporator 600 is heated, hence the liquid cooling fluid is boiled off, by the provision of thermal energy through the heating fluid of the first fluid system. The gaseous cleaning fluid is drawn from the evaporator 600 by activating the first and second fluid displacing elements 410 and 420 working as compressors and in parallel. The gaseous cleaning fluid is cooled in the heat exchangers 702 and 703, and the first and second fluid displacing elements 410 and 420 are cooled, by cooling fluid provided by the second fluid system 300. The gaseous cleaning liquid is condensed in heat exchanger 704, and this liquid cleaning fluid is returned to the storage tank 500. As the pressure

in the evaporator decreases in view of the pressure of the storage tank, at a certain moment in time, the first and second fluid displacing elements 410 and 420 working as compressors in parallel may not be sufficient anymore to overcome this pressure difference. A gas extraction phase part II (Ph XI) is started. The fluid path is changes to the one shown in figure 19, where the first and second fluid displacing elements 410 and 420 are set up to work as compressors in series, with intermediate cooling by heat exchanger 703. As such a higher pressure difference can be build up, and more liquid cleaning fluid can be recuperated by evaporation. The remaining gaseous cleaning fluid can during this end phase also be evacuated from the container 110 by opening the valves V6 and V7.

[0090] The cleaning process is finished and container can be opened now to take out the cleaned products. By opening the valve V19 and allowing water through the valves Vw1 and Vw2 to clean the tubing, the contamination and the remainders of the additives may be taken from the evaporator.

[0091] Although the present invention has been illustrated by reference to specific embodiments, it will be apparent to those skilled in the art that the invention is not limited to the details of the foregoing illustrative embodiments, and that the present invention may be embodied with various changes and modifications without departing from the scope thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein. In other words, it is contemplated to cover any and all modifications, variations or equivalents that fall within the scope of the basic underlying principles and whose essential attributes are claimed in this patent application. It will furthermore be understood by the reader of this patent application that the words "comprising" or "comprise" do not exclude other elements or steps, that the words "a" or "an" do not exclude a plurality, and that a single element, may fulfil the functions of several means recited in the claims. Any reference signs in the claims shall not be construed as limiting the respective claims concerned. The terms "first", "second", third", "a", "b", "c", and the like, when used in the description or in the claims are introduced to distinguish between similar elements or steps and are not necessarily describing a sequential or chronological order. Similarly, the terms "top", "bottom", "over", "under", and the like are introduced for descriptive purposes and not necessarily to denote relative positions. It is to be understood that the terms so used are interchangeable under appropriate circumstances and embodiments of the invention are capable of operating according to the present invention in other sequences, or in orientations different from the one(s) described or illustrated above.

Claims

1. A cleaning apparatus for cleaning textile products, protective gear and/or equipment, said apparatus comprises a container for receiving said textile products, protective gear and/or equipment, said container being adapted to receive a compressed gas, said compressed gas being in gaseous, liquid or supercritical liquid state, said apparatus further comprises a first and a second, mutually separated fluid system, said first fluid system comprises a first fluid conducting means in said container to heat the compressed gas in gaseous, liquid or supercritical liquid state in said container, said second fluid system comprises a second fluid conducting means in said container to cool the compressed gas in gaseous, liquid or supercritical liquid state in said container.

2. A cleaning apparatus according to claim 1, wherein the apparatus comprises a vessel in said container, said vessel being adapted to receive said textile products, protective gear and/or equipment.

3. A cleaning apparatus according to any one of the claims 1 to 2, wherein each of said fluid conducting means comprises a tubing having the shape of a helix positioned within said container.

4. A cleaning apparatus according to claim 3, wherein each tubing comprises two mutually parallel and adjacent conduits.

5. A cleaning apparatus according to any one of the claims 3 to 4, wherein the tubing of the first fluid conducting means and the tubing of the second fluid conducting means together form a double helix.

6. A cleaning apparatus according to any one of the claims 1 to 5, wherein said first fluid system comprises a heat exchanger to heat fluid passing in said first fluid system.

7. A cleaning apparatus according to any one of the claims 1 to 6, wherein said second fluid system comprises a heat exchanger to cool fluid passing in said first fluid system.

8. A cleaning apparatus according to any one of the claims 1 to 7, wherein said first fluid system comprises a fluid

displacement means to displace fluid passing in said first fluid system, said second fluid system comprises a fluid displacement means to displace fluid passing in said second fluid system.

9. A cleaning apparatus according to claim 8, wherein the apparatus comprises a control means to control the fluid displacement means of the first and second fluid system.

10. A cleaning apparatus according to any one of the claims 1 to 9, wherein said apparatus comprises a fluid displacement means for displacing the compressed gas, said fluid displacement means comprises at least a first and a second fluid displacing element, both adapted to displace a liquid and to compress a gaseous fluid, both fluid displacement elements comprising a fluid inlet adapted to receive fluid from the container, and a fluid outlet adapted to provide displaced or compressed fluid to a tubing system off stream the fluid displacement means, the fluid displacement means further comprises a fluid coupling between the outlet of the first displacement element and the inlet of the second displacement element, the fluid displacing element comprising a valve system to couple the outlet of the first displacement element to either the tubing system off stream the fluid displacement means or the inlet of the second displacement element.

11. A cleaning apparatus according to claim 10, wherein the apparatus comprises a heat exchanger to cool the fluid between the outlet of the first fluid displacement element and the inlet of the second fluid displacement element when the fluid displacing element couples the outlet of the first displacement element to the inlet of the second displacement element.

12. A cleaning apparatus according to any one of the claims 10 to 11, wherein said first fluid displacement element is or is part of a plunger displacement compressor.

13. A cleaning apparatus according to any one of the claims 10 to 12, wherein fluid displacement means comprises at least a third fluid displacing element, adapted to displace a liquid and to compress a gaseous fluid, said third fluid displacement elements comprising a fluid inlet adapted to receive fluid from the container, and a fluid outlet adapted to provide displaced or compressed fluid to a tubing system off stream the fluid displacement means, the fluid displacement means further comprises a fluid coupling between the outlet of the third displacement element and the inlet of the second displacement element, the fluid displacing element comprising a valve system to couple the outlet of the third displacement element to either the tubing system off stream the fluid displacement means or the inlet of the second displacement element.

14. A cleaning apparatus according to claim 13, wherein the third fluid displacing element is adapted to displace fluid in parallel to the fluid displacing element.

15. The use of a cleaning apparatus according to any one of the preceding claims, to clean textile products, protective gear and/or equipment.

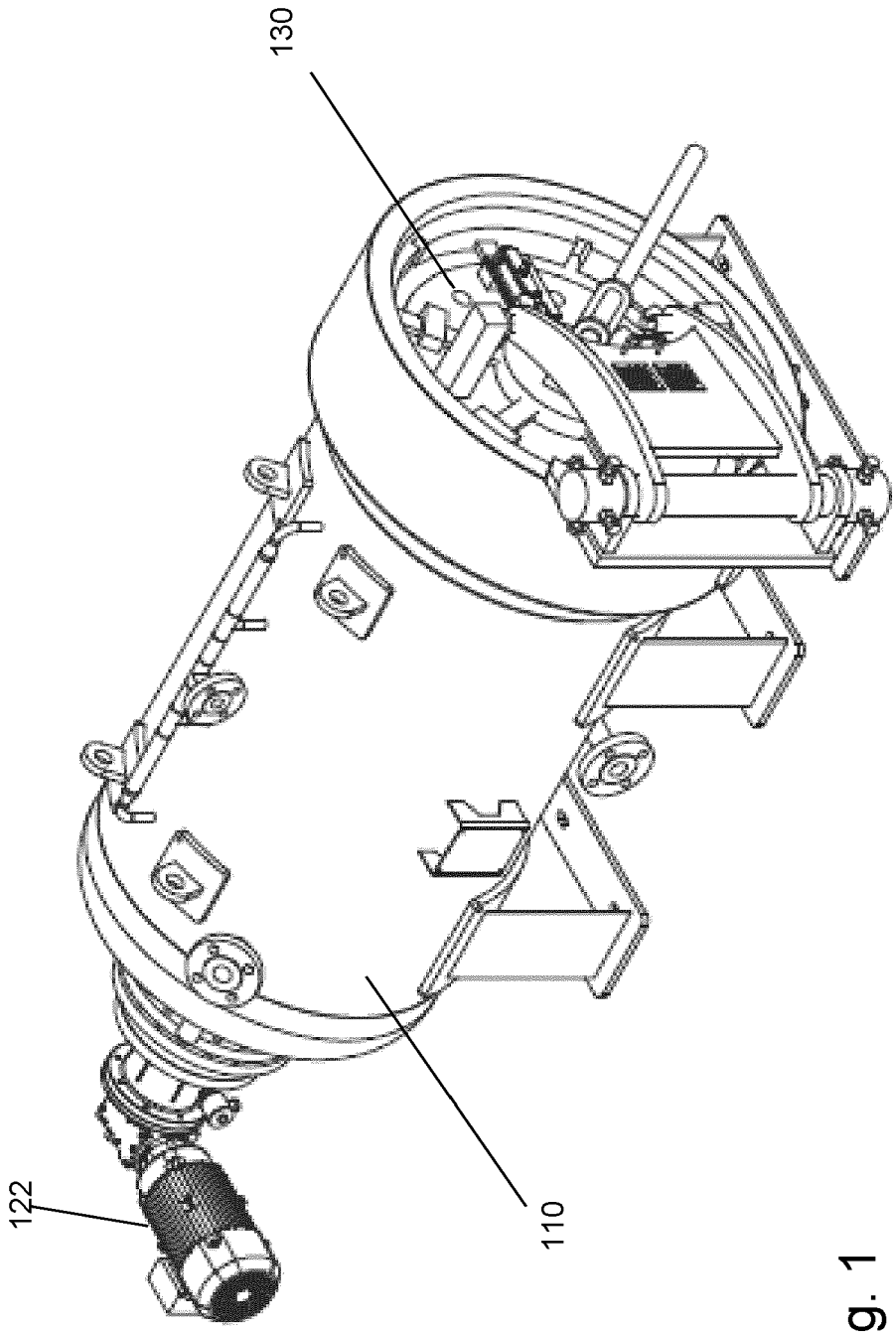

Fig. 1

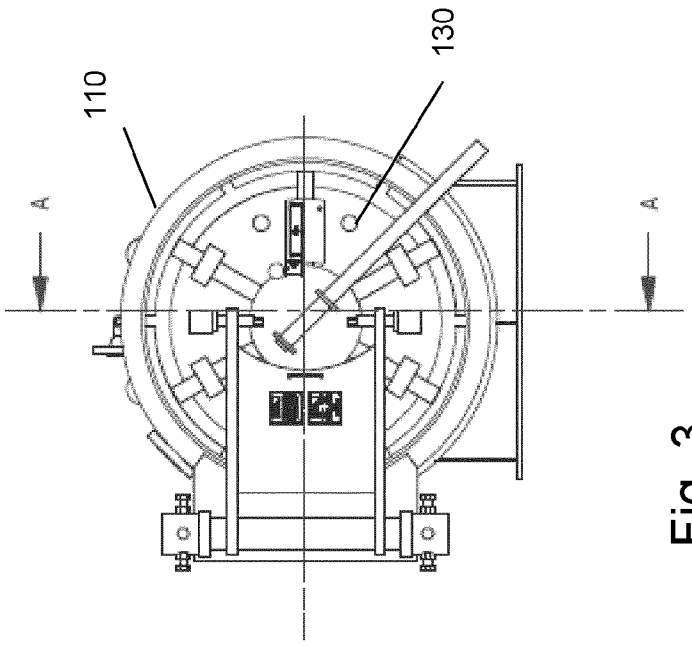

Fig. 3

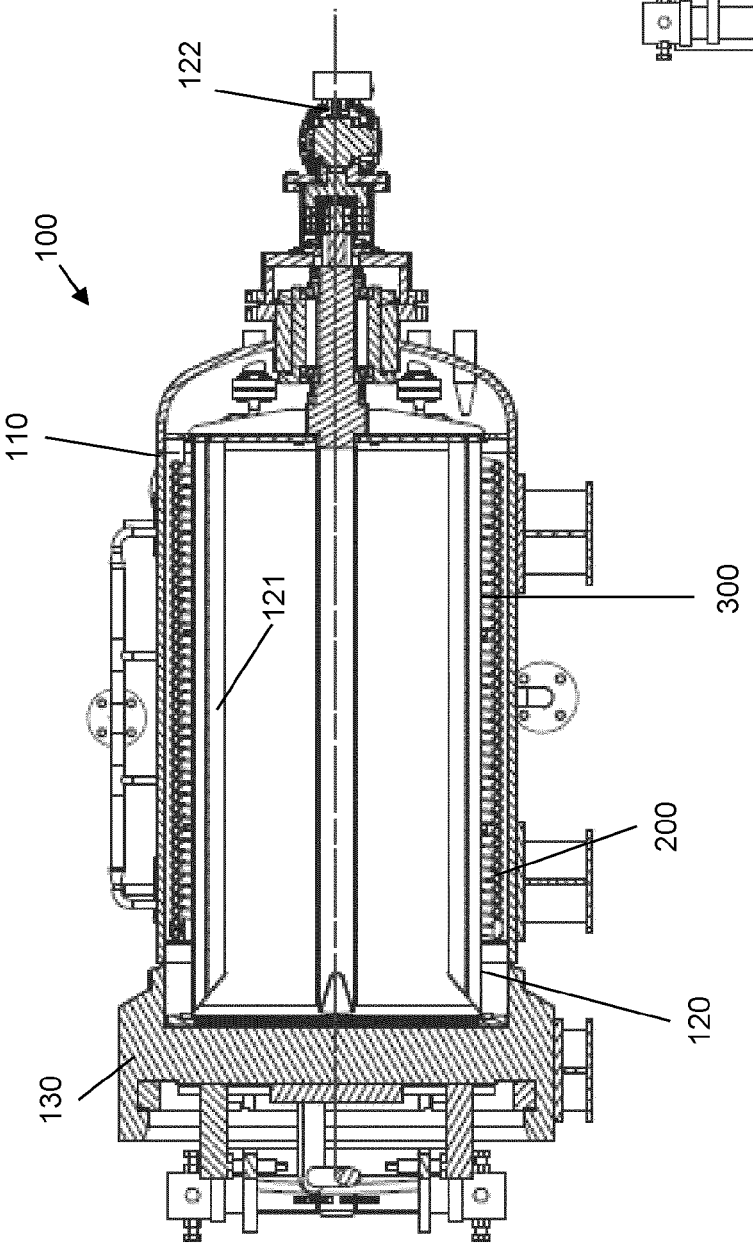

Fig. 2

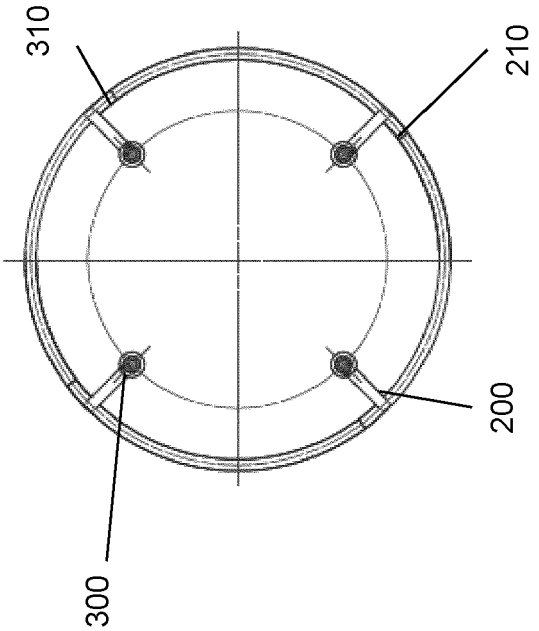

Fig. 5

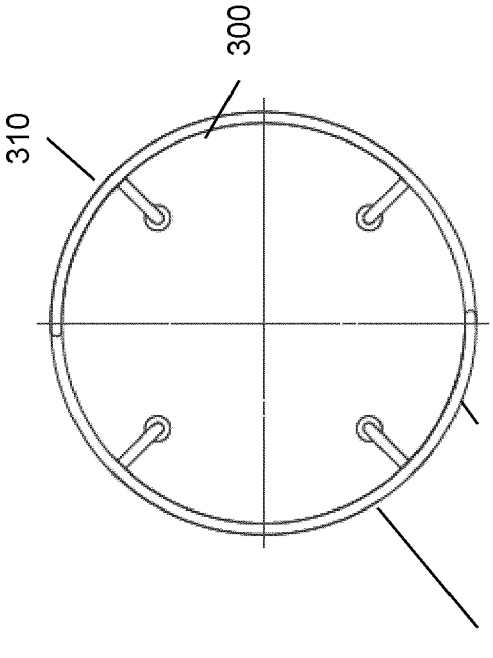

Fig. 6

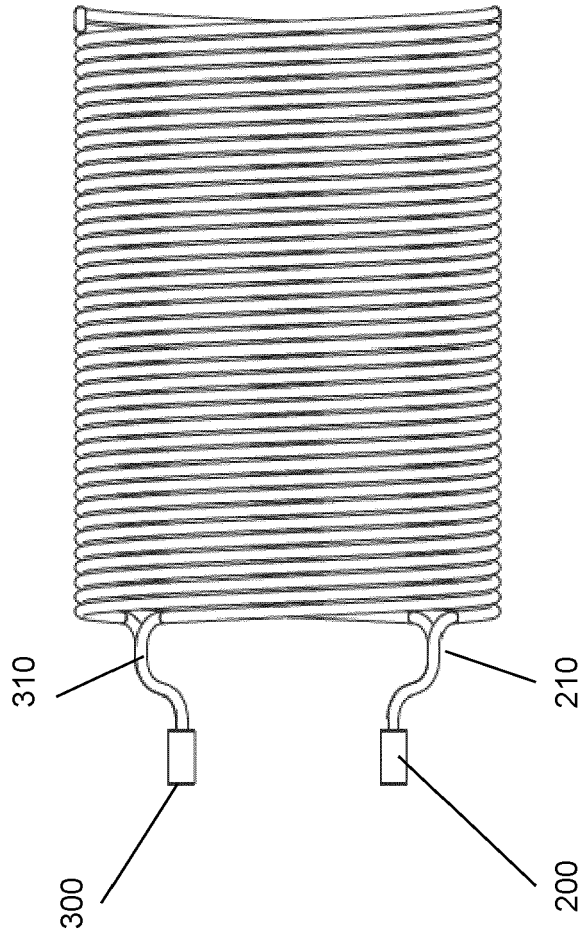

Fig. 4

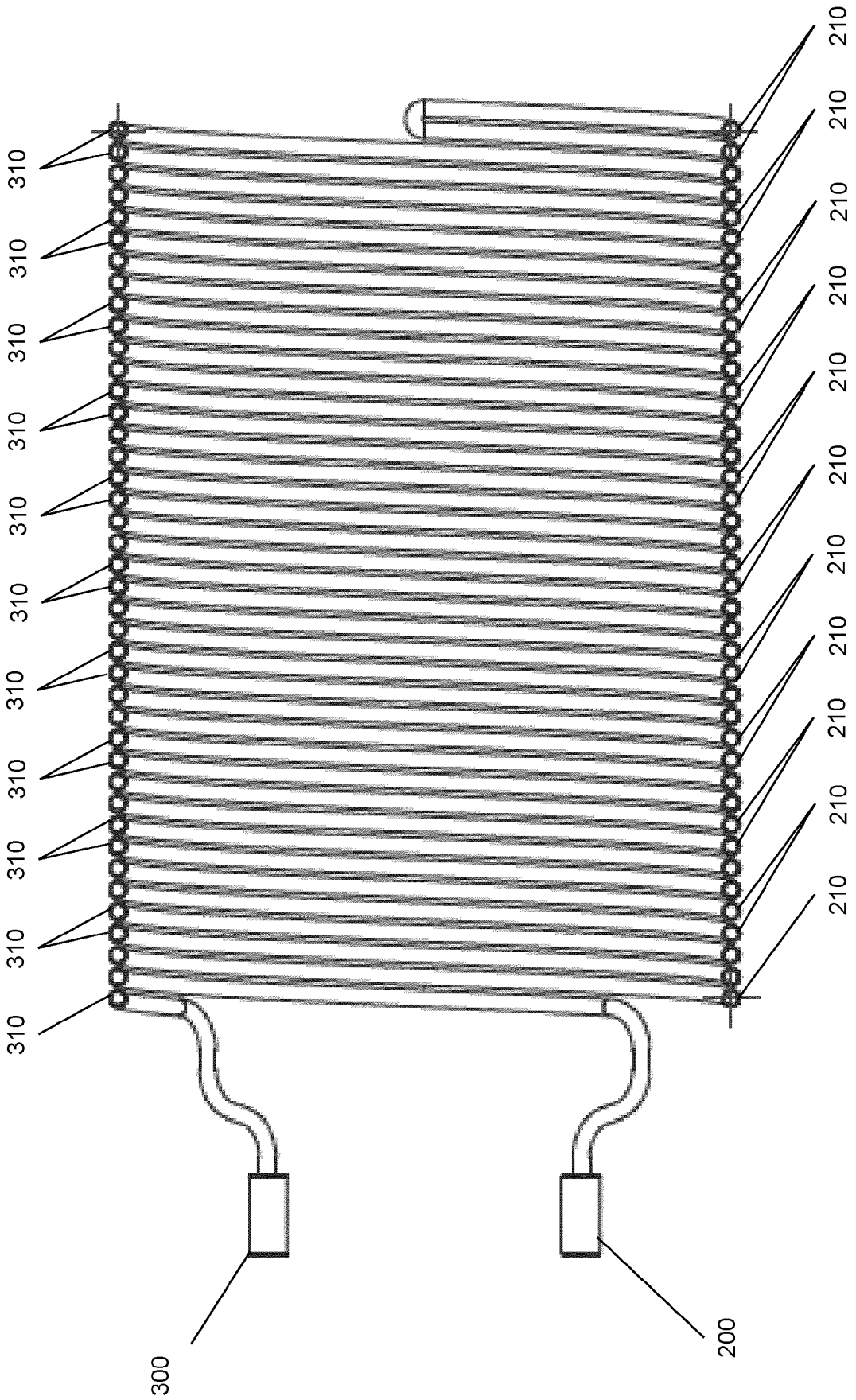
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Fig. 7

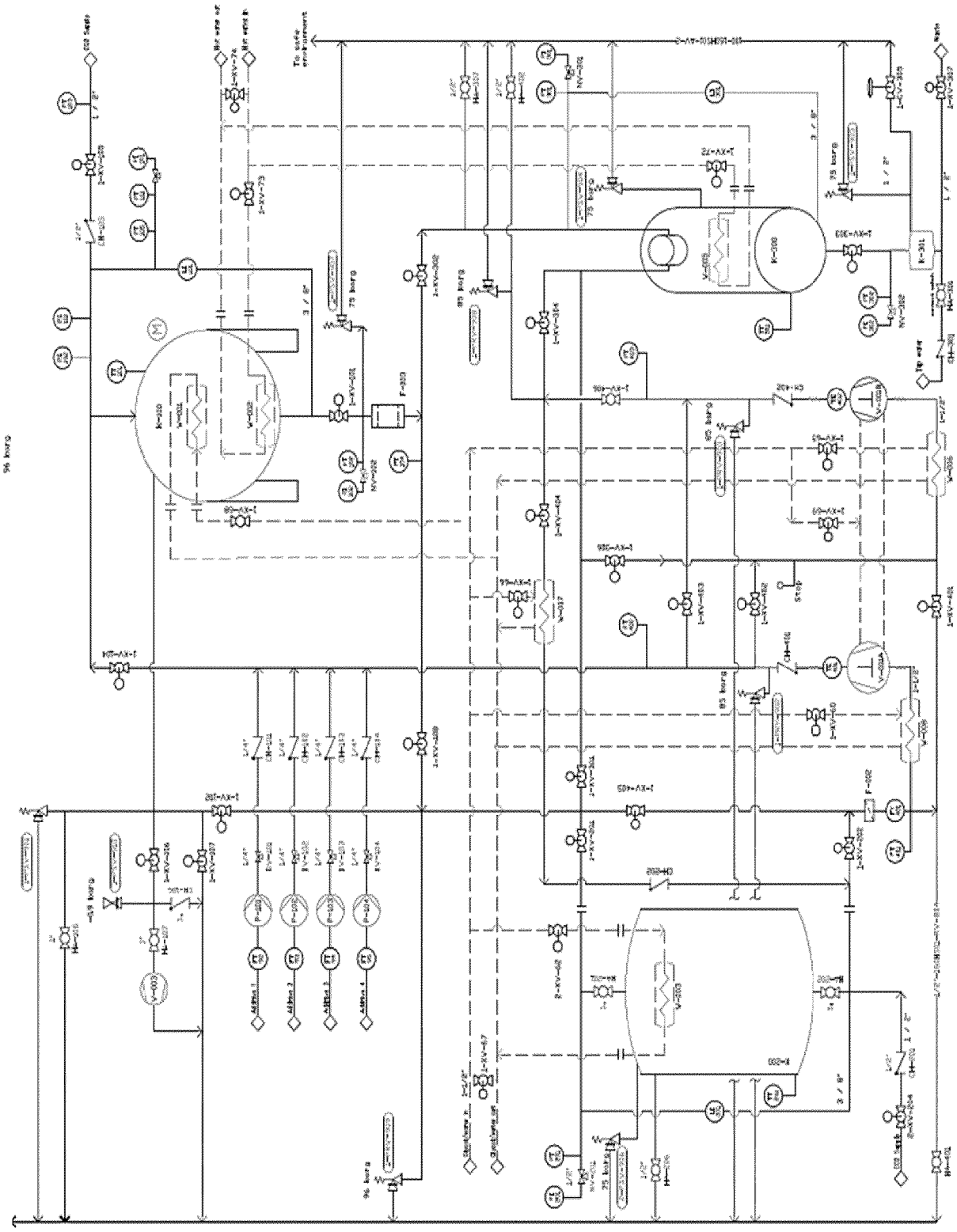
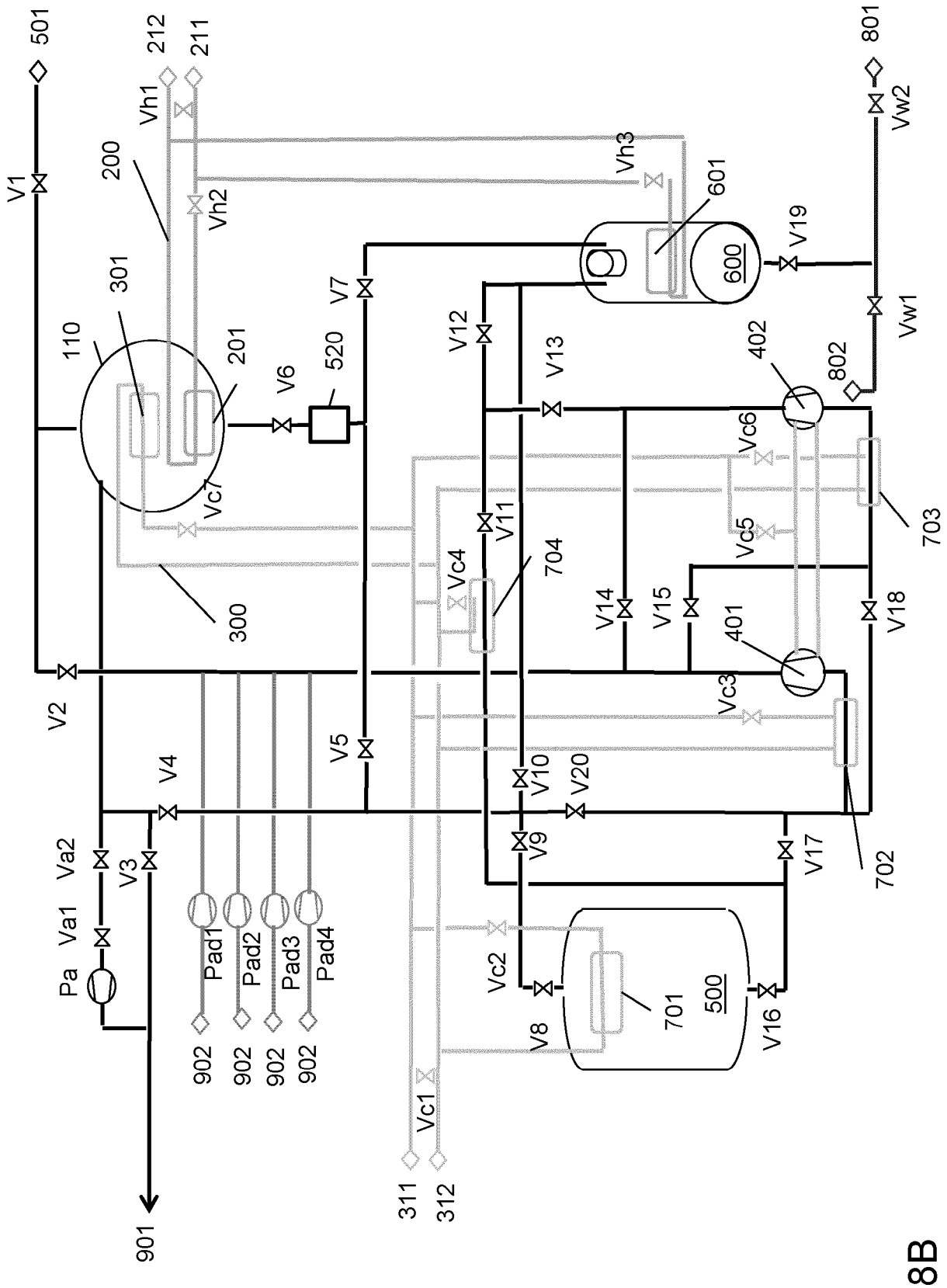


Fig. 8A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212
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Fig. 8B

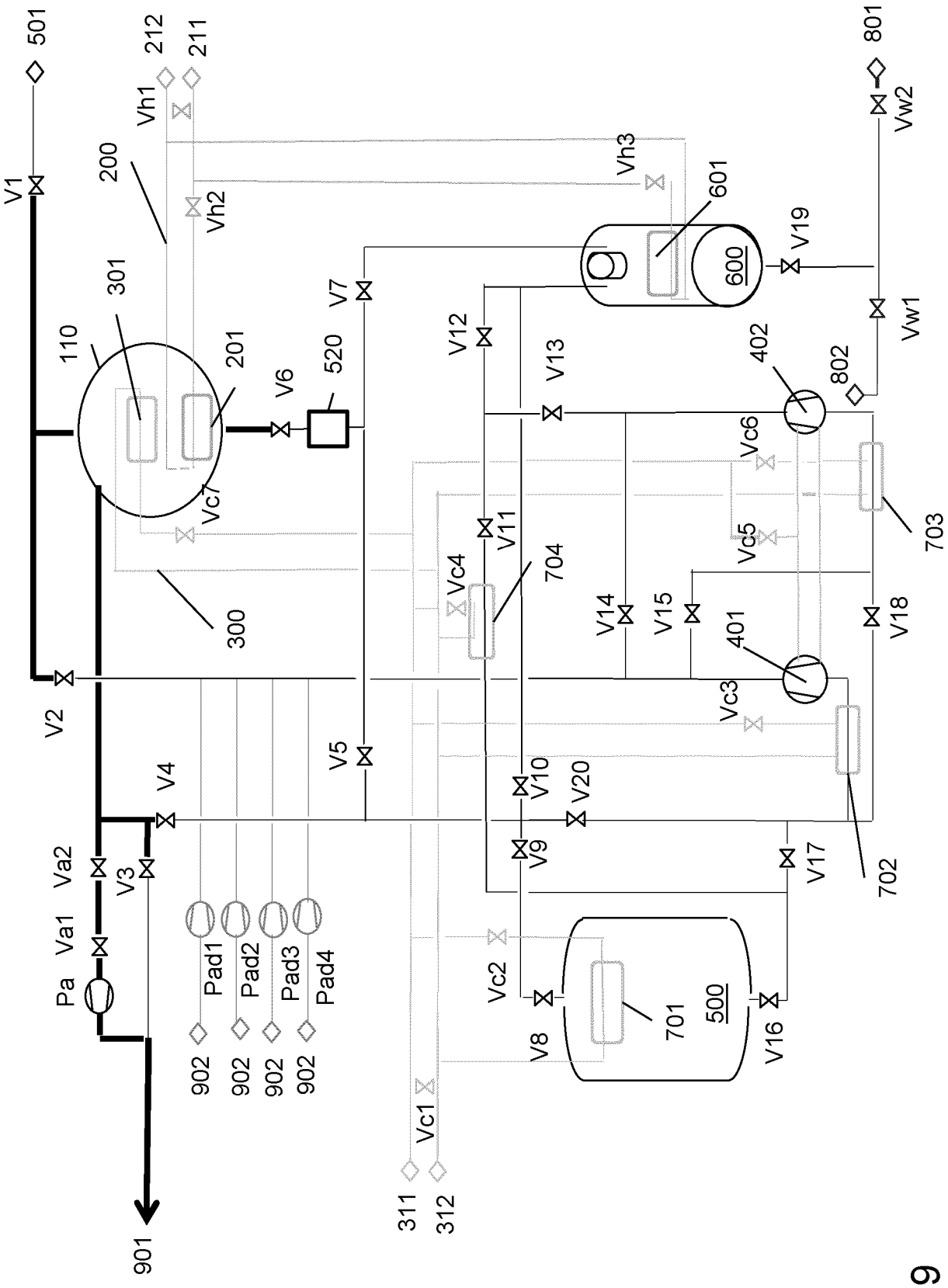
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Fig. 9

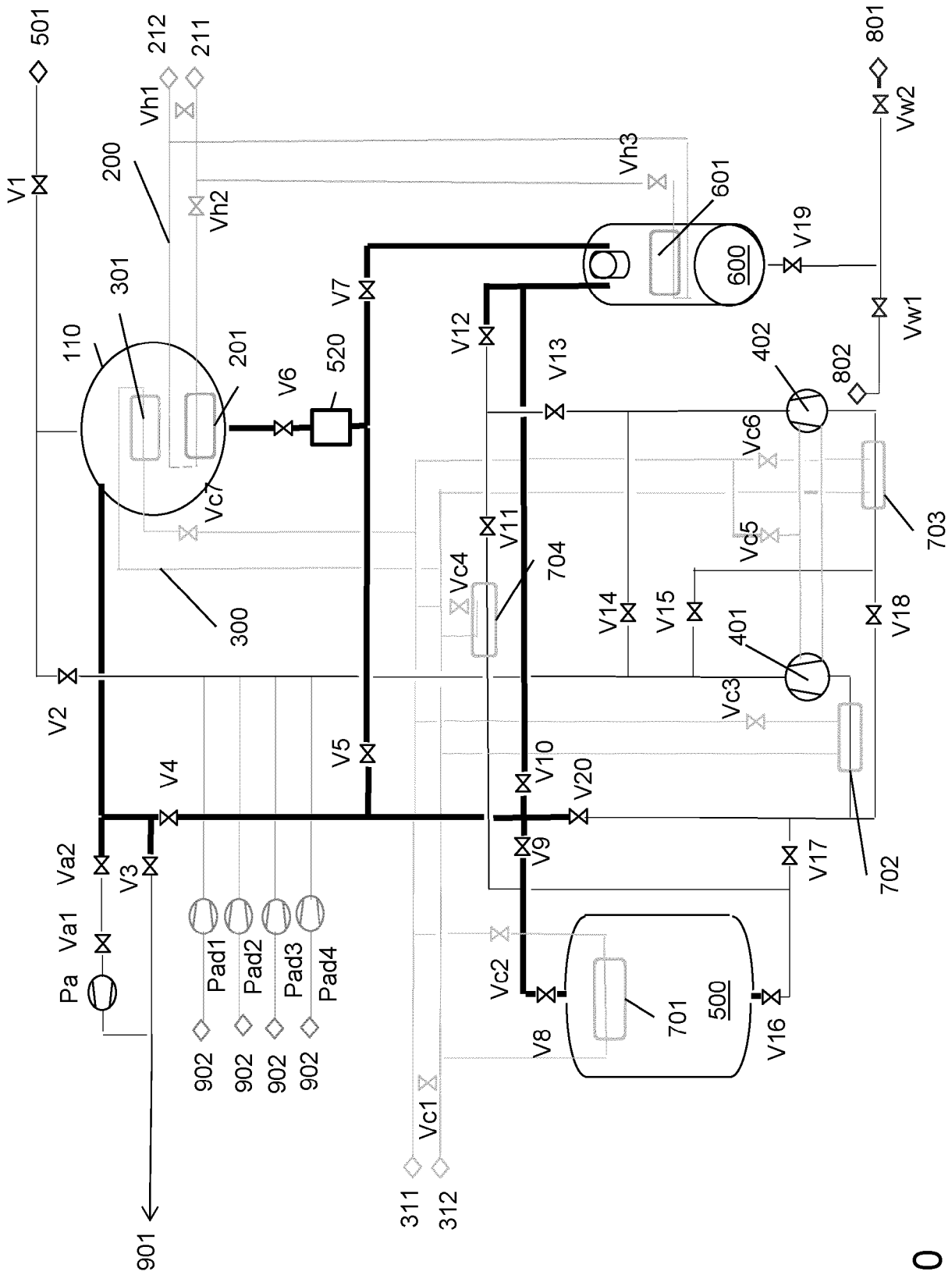
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Fig. 10

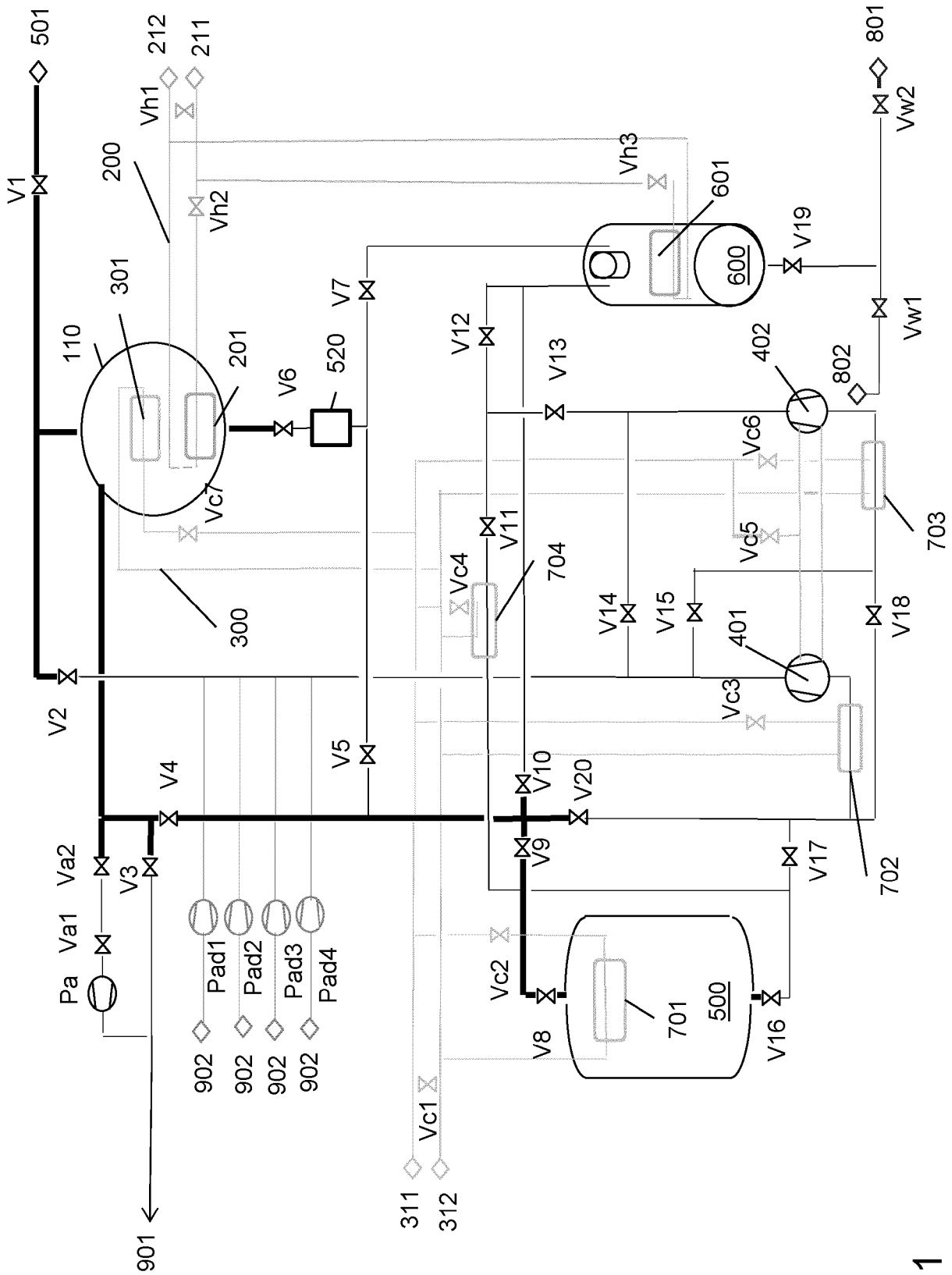
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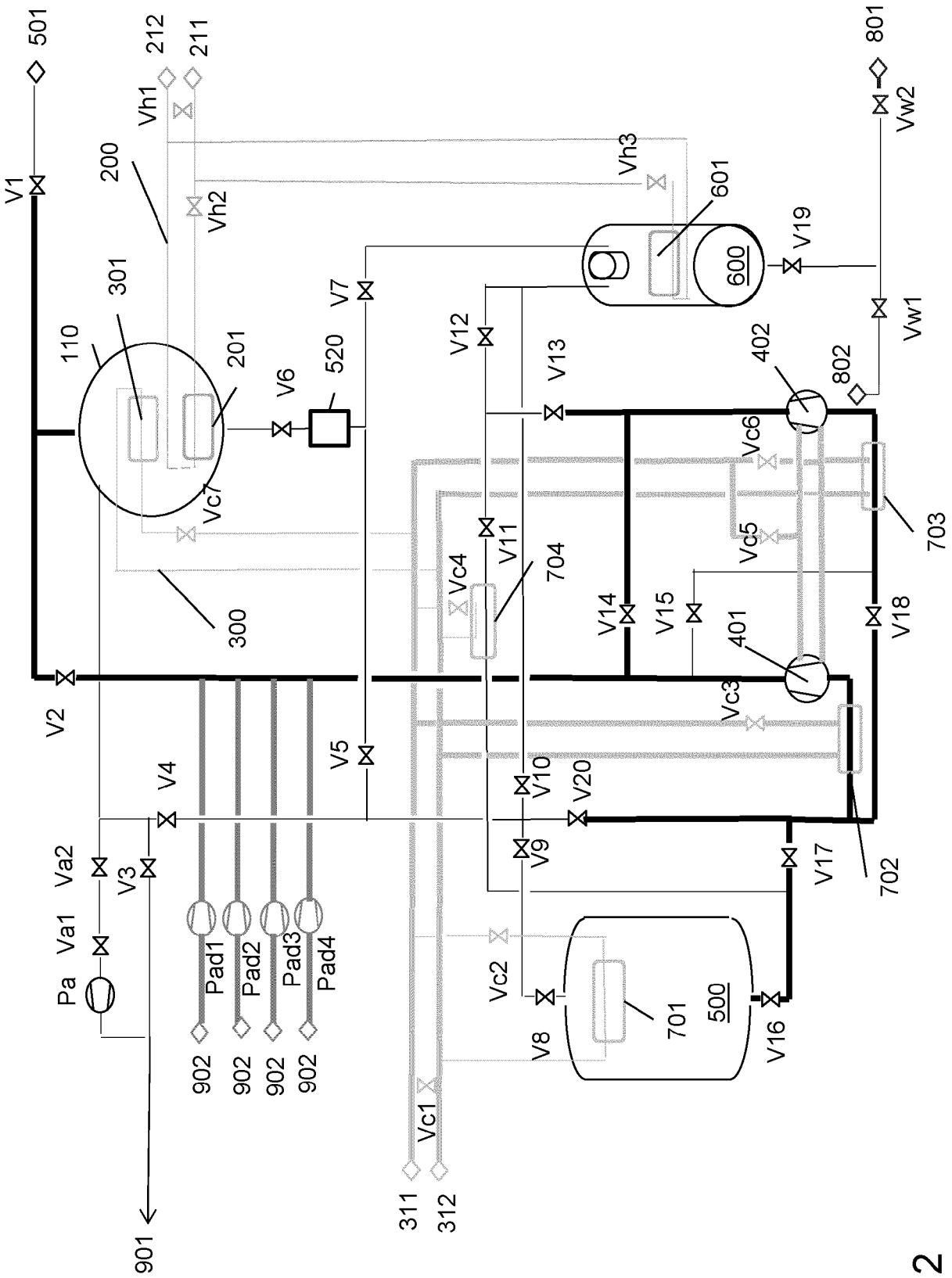
Fig. 11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Vc7
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Vc3
V5
V4
V10
V20
V9
V17
Va2
V3
Va1
Pa
Pad1
Pad2
Pad3
Pad4
Vc2
V8
701
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Fig. 12

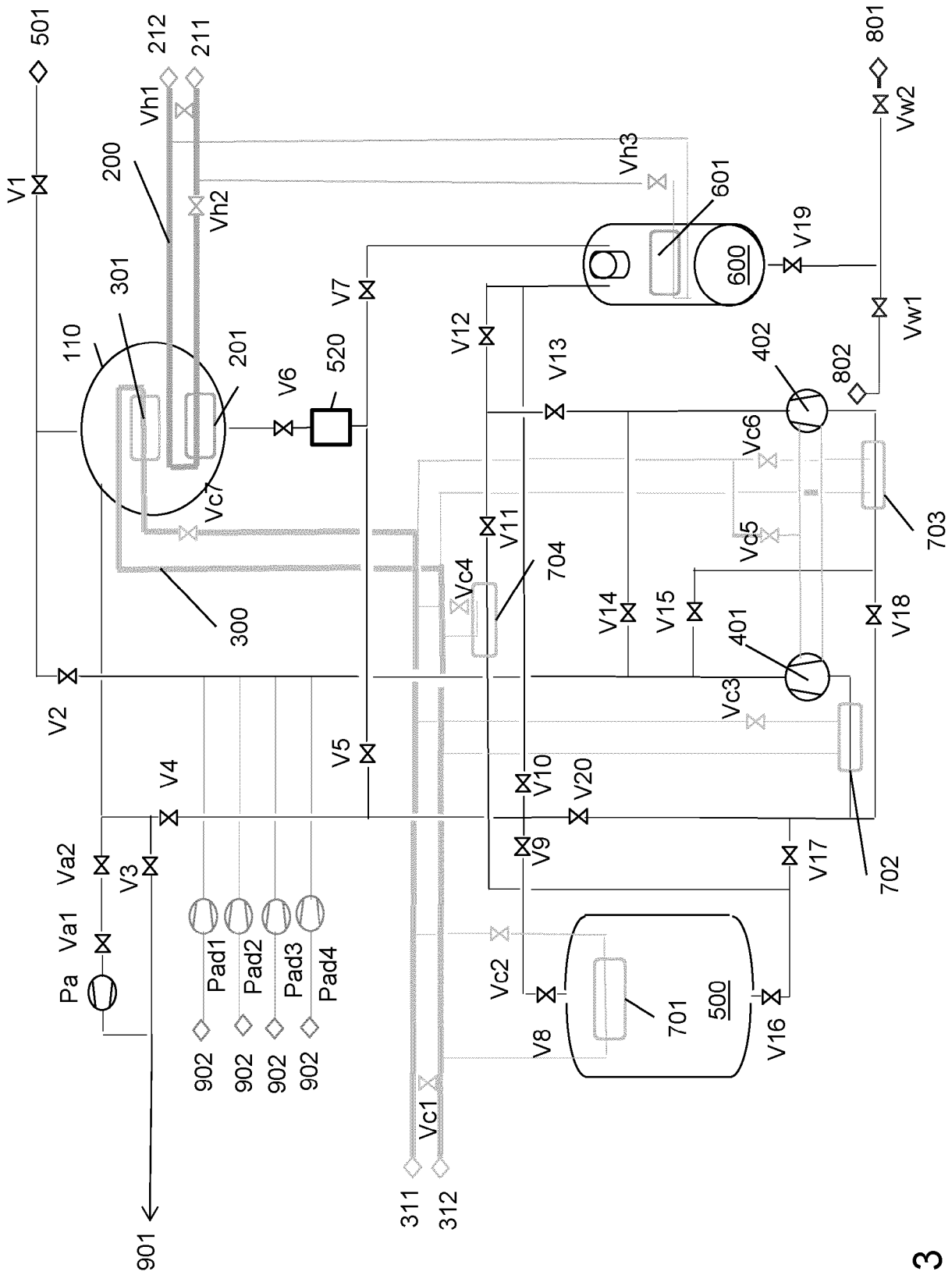
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Fig. 13

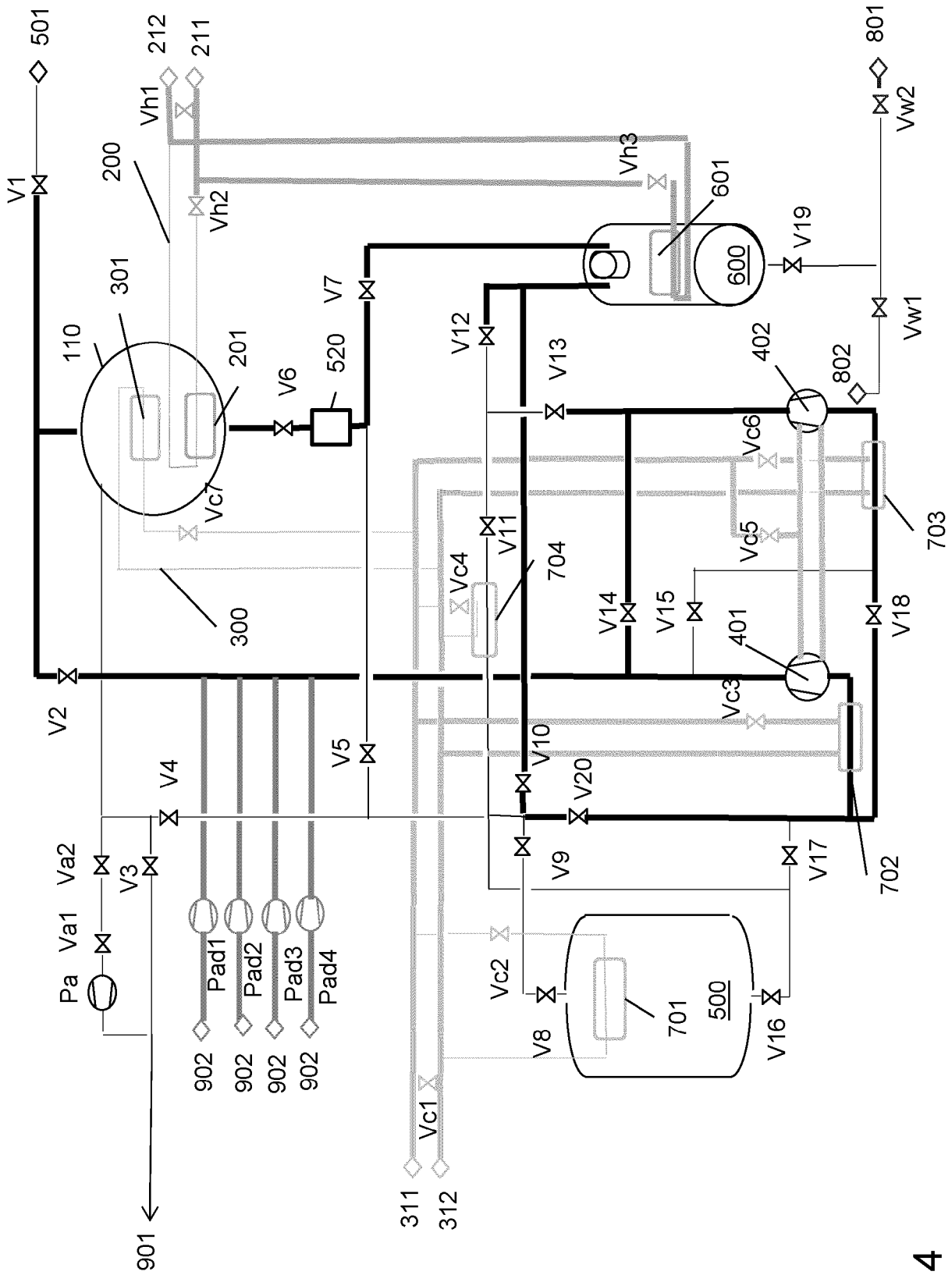
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Fig. 14

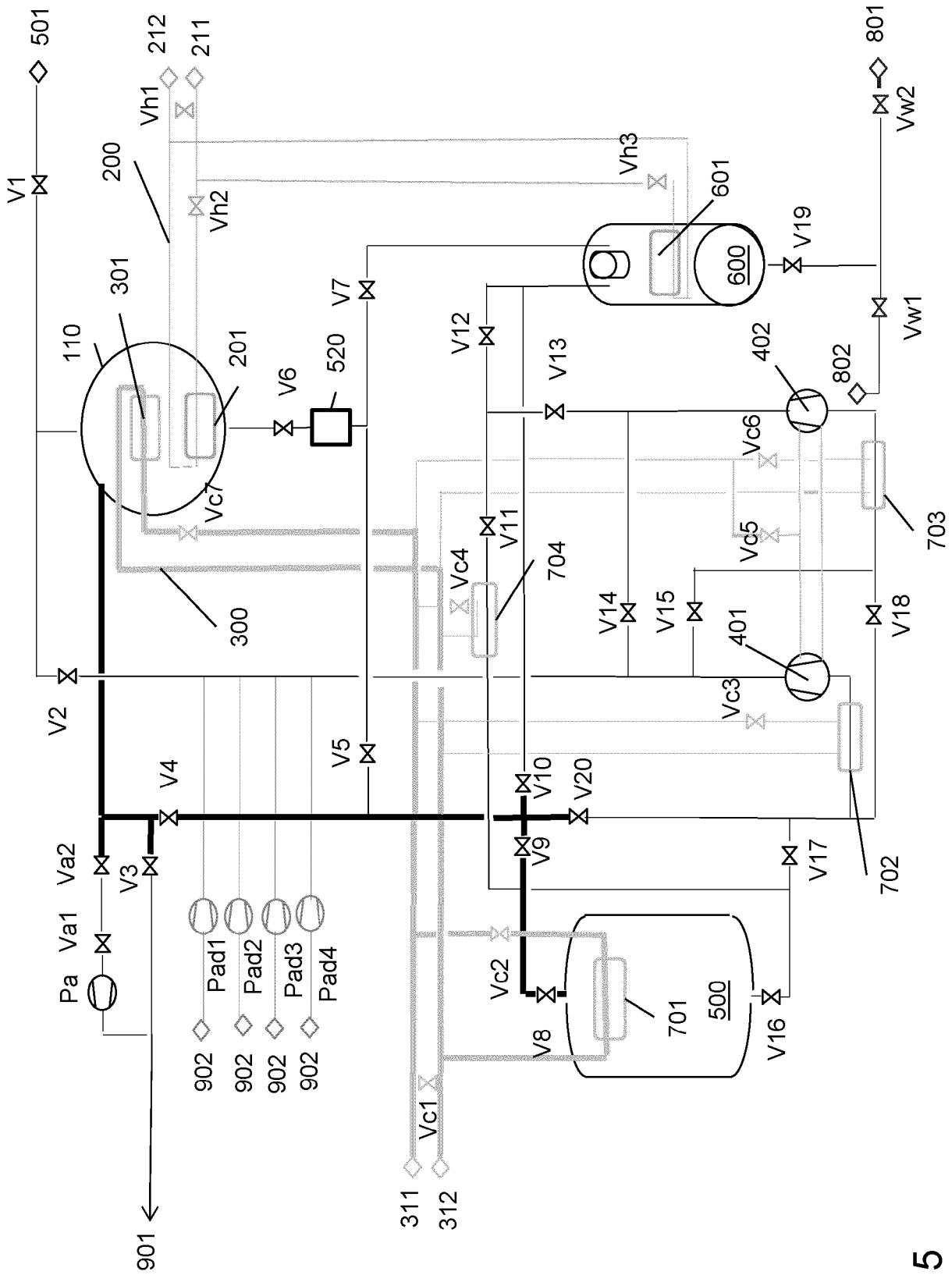
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Fig. 15

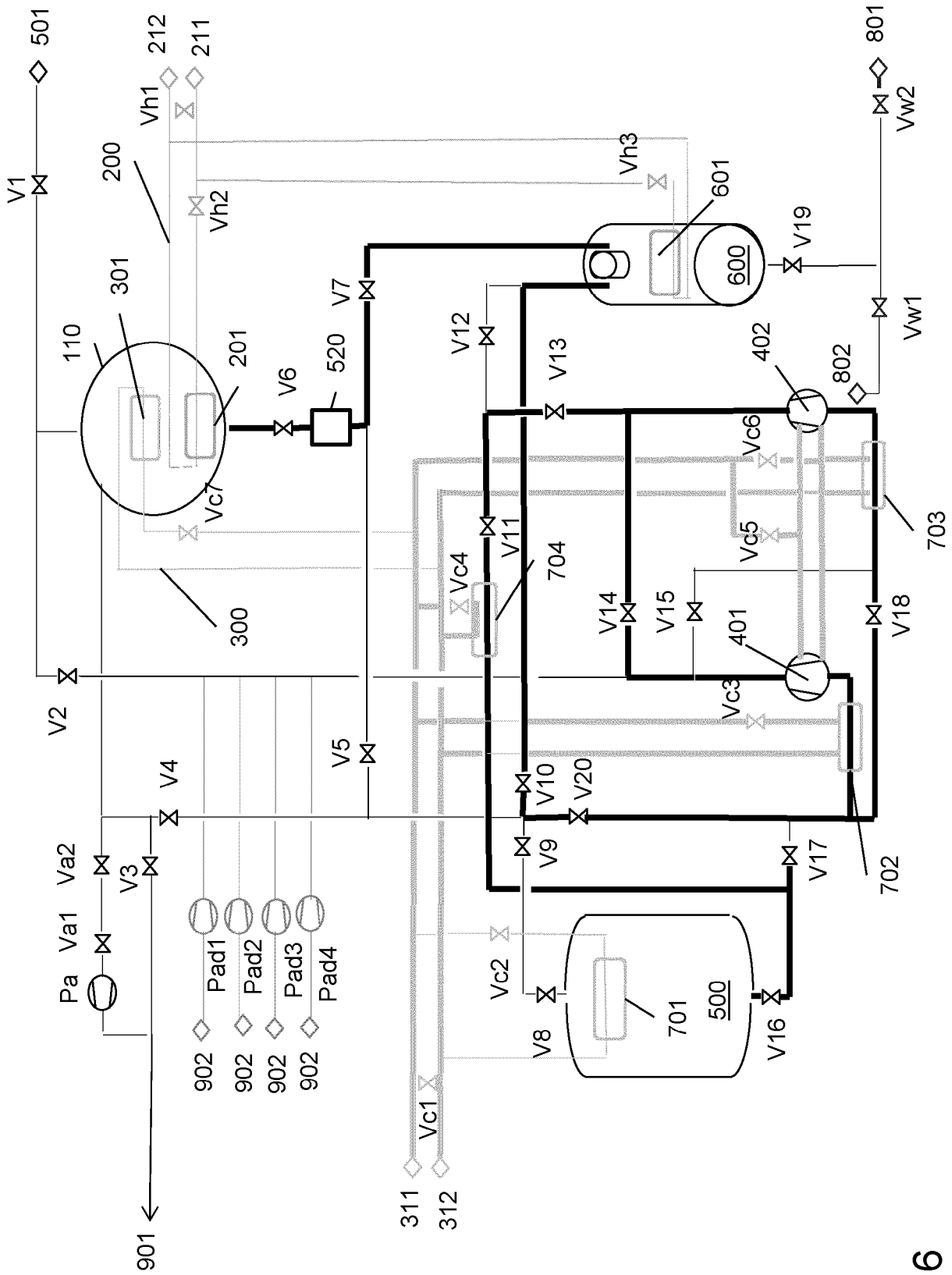
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Fig. 16

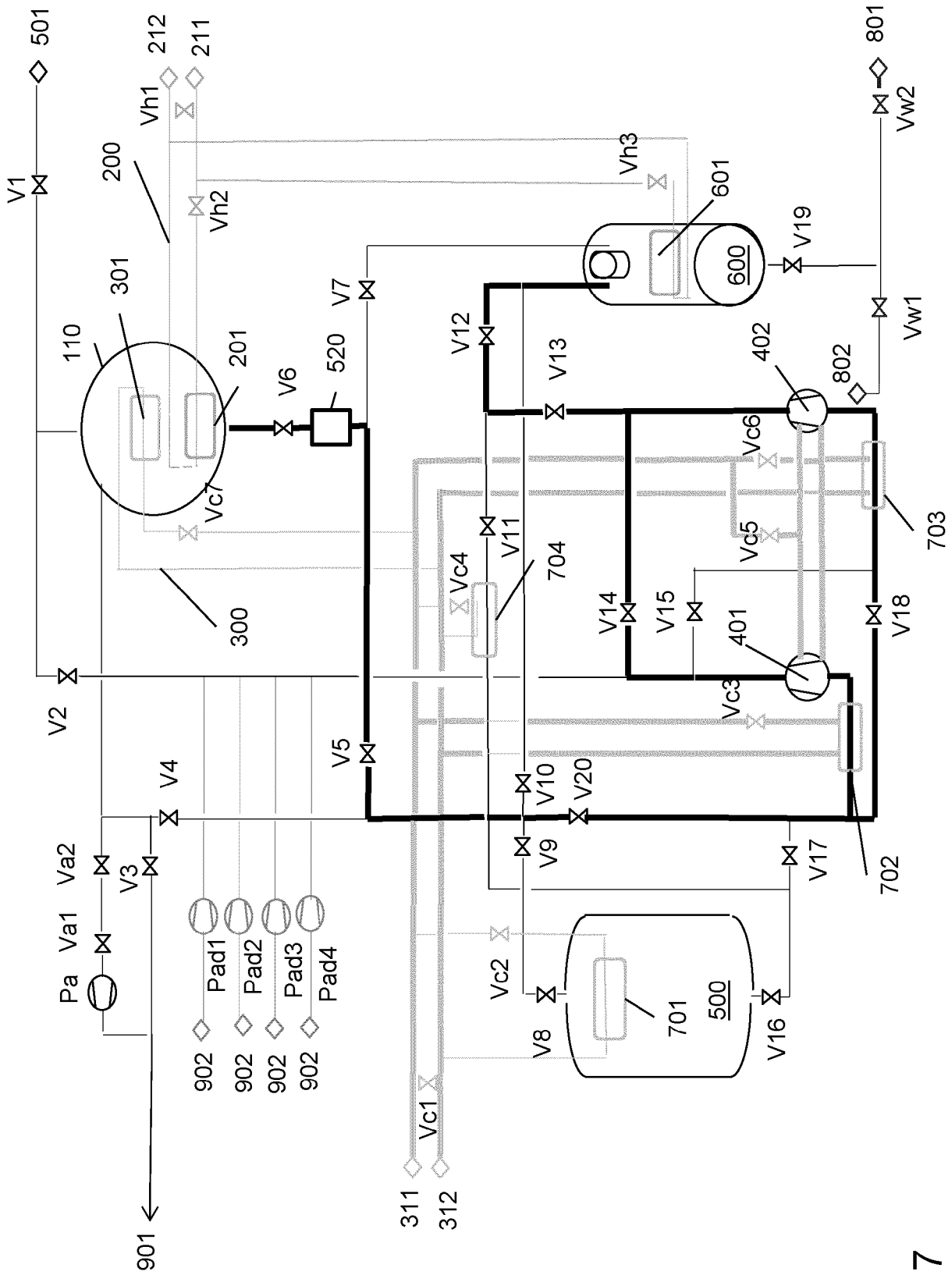
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Fig. 17

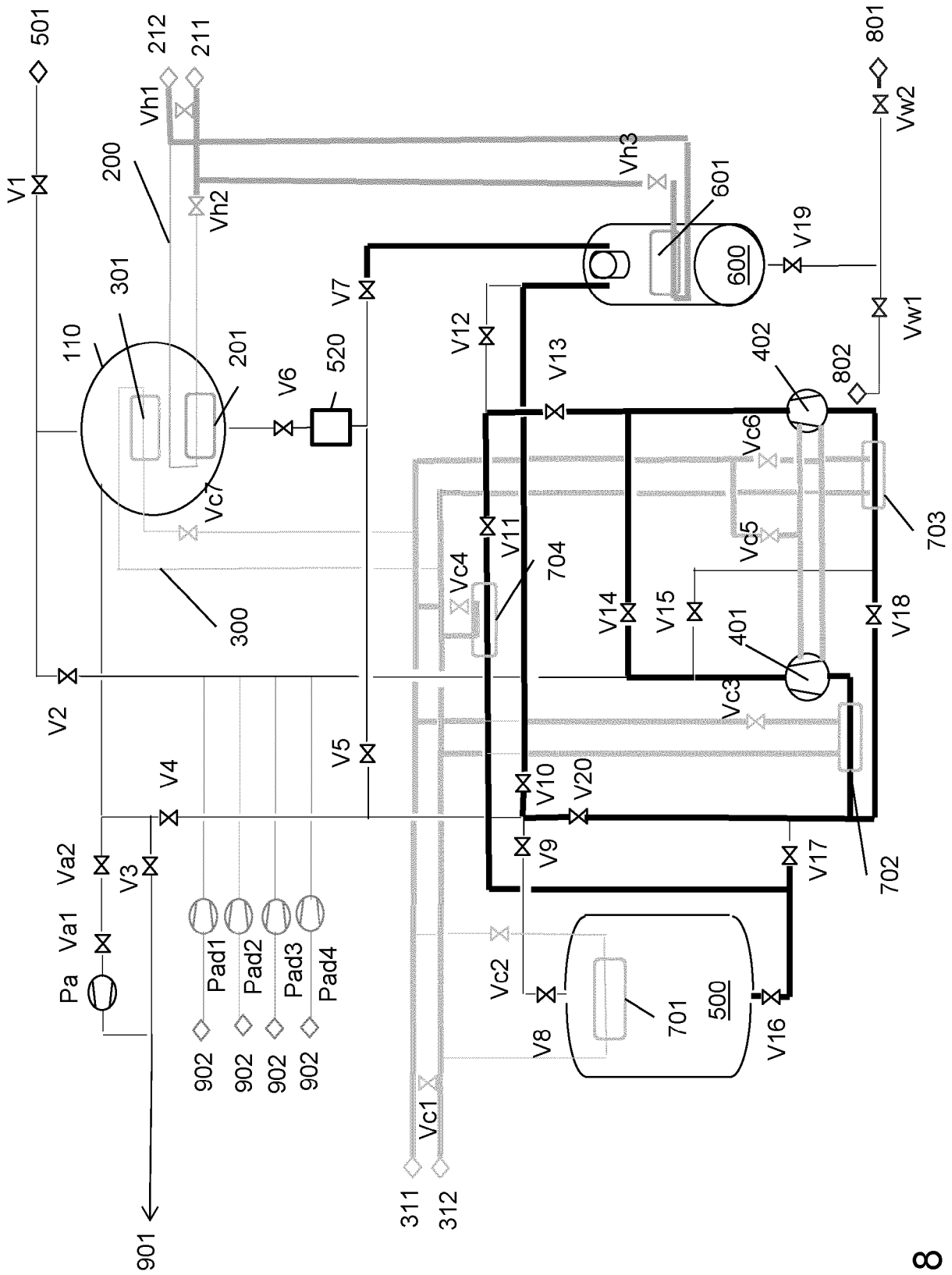
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Fig. 18

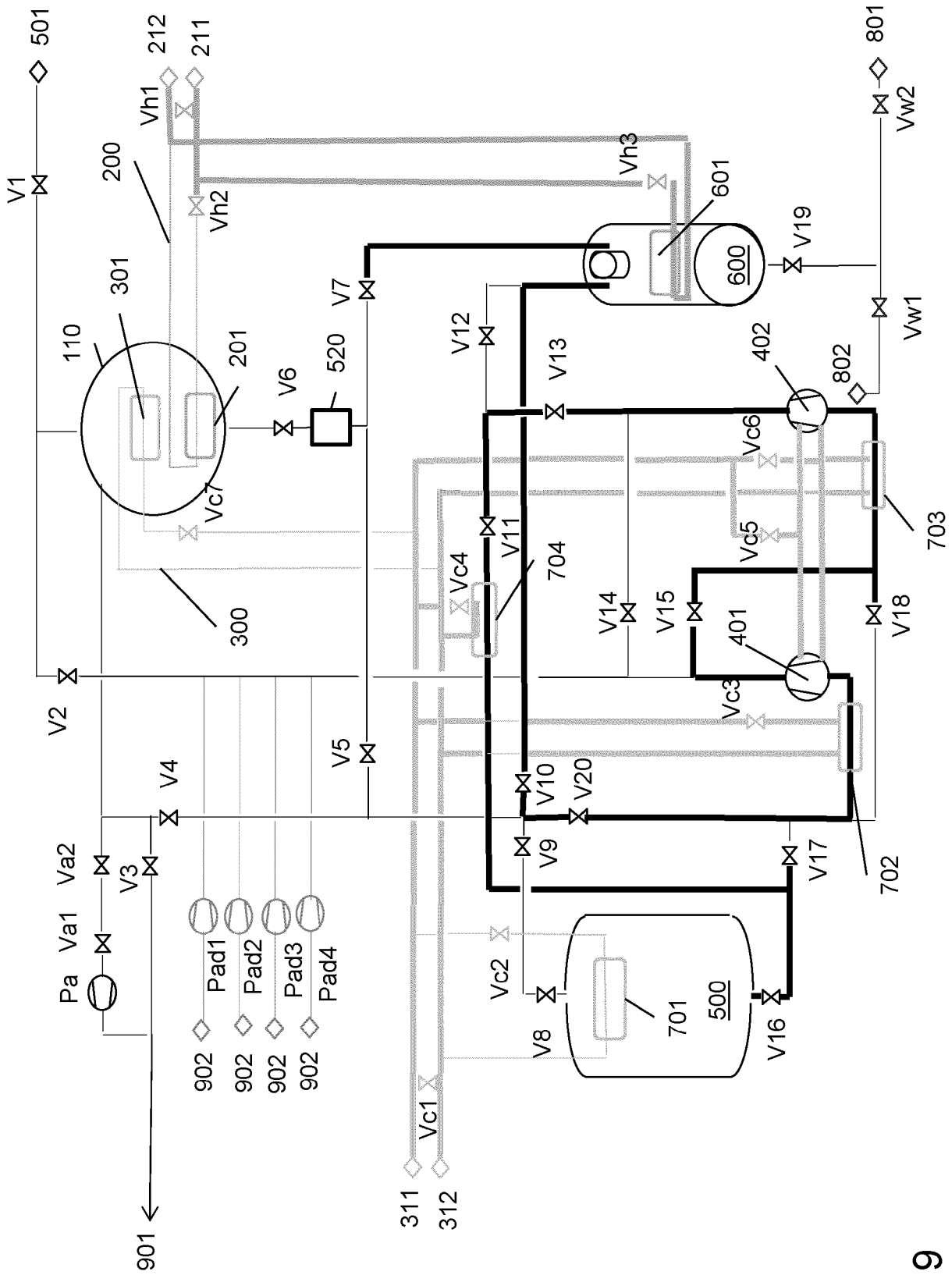
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Fig. 19

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EUROPEAN SEARCH REPORT

Application Number
EP 23 16 3869

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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A	* page 1, line 5 - line 11 * * page 1, line 44 - line 78 * * page 3, line 123 - page 4, line 6 * * figure 1 *	4-14	ADD. D06F43/02
X	DE 20 2018 105980 U1 (MULTIMATIC ILSA DEUTSCHLAND GMBH & CO KG [DE]) 22 January 2020 (2020-01-22)	1,2,7-9, 15	
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A	US 5 412 958 A (ILIFF ROBERT J [US] ET AL) 9 May 1995 (1995-05-09) * column 2, line 67 - column 3, line 9; figure 1 * * column 3, line 28 - line 48 * * column 6, line 34 - line 44; figure 2 * * column 7, line 45 - line 64 *	1-15	

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D06F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	7 September 2023	Sabatucci, Arianna

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