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DESCRIPTION

Description

[0001] This invention relates to a medical contact shock freezer adapted for fast freezing a plurality of individual bags containing blood plasma and to a method of freezing medical liquids.

[0002] Blood plasma bags are commonly used to store, transport and dispense blood plasma and comprise flexible plastics walls which may be made of polyethylene, polypropylene or plasticized PVC. In order to ensure plasma quality, once the plasma has been obtained, for example by plasmapheresis, it is desirable for the plasma contained within a filled, sealed plasma bag to be completely frozen to a temperature of -30°C or less within a short time period. The step of rapidly freezing the plasma, for example from its collection temperature or from room temperature to -30°C , is facilitated by use of a contact shock freezer in which a plurality of plasma bags are pressed between cooling plates which are chilled by a circulating coolant. Once frozen, the plasma bags are transferred to a medical storage freezer which may be maintained at a temperature of -30°C , -50°C or below.

[0003] Contact shock freezers require a high refrigeration power in order to rapidly remove a significant quantity of heat from the sealed plasma bags. For example, a cooling power of over 1.5 kW is required to reduce the temperature of forty-eight 0.25l bags of plasma from 32°C to -30°C in less than 60 minutes. Consequently, contact shock freezers have typically been based on refrigeration circuits which use large, high power semi-hermetic compressors and large quantities of refrigerant. The power requirements for the medical storage freezers to which the shock frozen plasma bags are transferred is significantly lower and the cooling circuits for such medical storage freezers are thus designed accordingly.

[0004] FR2632391 A1 relates to a rapid freezing device for bags of plasma or similar blood derivatives. WO 2008/112566 A2 provides a multistage refrigeration system. CN112195015 A provides a mixed refrigerant and a refrigerating system. WO 2015/045354 A1 provides a refrigerating device capable of effectively eliminating problems due to the formation of dry ice from carbon dioxide (R744). JP 2014 070832 A provides an ultra-low temperature refrigerator for storing cells and microbes. US 2018/146799 A1 and US 2018/146800 A1 disclose refrigerated display cases.

[0005] In accordance with one of its aspects, the present invention provides a medical contact shock freezer in accordance with claim 1. The dependent claims define preferred or alternative features.

[0006] In one of its aspects, the present invention is based upon the realisation that the combination of a cascade refrigeration system, particularly using fully hermetic compressors,

can be adapted to provide a suitable cooling system for such a contact shock freezer; in the medical contact freezer of claim 1 each of the first stage compressor and the second stage compressor is a fully hermetic compressor. It is particularly surprising that such a contact shock freezer system can also use environmentally friendly green refrigerant gasses which are generally less efficient than the refrigerants traditionally used in high power contact shock freezer refrigeration circuits. Thus, the present invention provides, in one of its aspects, a surprising way of providing a contact shock freezer which uses environmentally friendly green refrigerant gasses, specifically hydrocarbon refrigerant gasses (and thus avoids the need to use refrigerant gasses in a contact shock freezer whose use is less desirable or outlawed, for example CFCs (ChloroFluoroCarbons), HCFCs (HydroChloroFluoroCarbons) and HFCs) by the use of a cascade refrigeration system for its contact shock freezer; in the medical contact freezer of claim 1 the first stage refrigerant is refrigerant grade propane and the second stage refrigerant is refrigerant grade ethane.

[0007] As used herein, the term contact shock freezer means a freezer which is configured to clamp the individual bags containing a medical liquid between the freezing plates during the freezing process such that the surfaces of the bags in contact with the freezing plates are flattened; this increases the contact area and improves heat transfer. Sufficient force may be applied to clamp the bags between the freezing plates such that a pressure which is ≥ 0.1 bar or ≥ 0.2 bar and/or ≤ 0.5 bar is generated in the medical liquid within the bags.

[0008] Each bag to be frozen may have a nominal volume of 500 ml; in this case, each bag may contain about 250 ml of plasma, for example from a whole blood donation of 500 ml.

[0009] Each pair of freezing plates is preferably substantially horizontal; this facilitates loading and unloading of the individual bags, for example by arranging the individual bags of medical liquid to be frozen on a heat conductive tray and loading the tray carrying the individual bags between the freezing plates when in their loading position. Thus, to facilitate loading and unloading, the freezing plates are preferably arranged at an angle of less than 30° to the horizontal. An improvement in the freezing cycle can be obtained by arranging the freezing plates at a small angle to the horizontal, for example at an angle of at least 2° or at least 3° with respect to the horizontal; this helps to mitigate against unintentional inclusion of air in the bags. An angle of between 3° and 10° , notably 5° , to the horizontal provides an advantageous effect combined with a configuration which facilitates loading and unloading of the bags.

[0010] The or each pair of freezing plates may define an operating surface, that is to say a surface at which individual bags can be arranged for freezing, which has an area ≥ 0.25 m², ≥ 0.3 m², ≥ 0.4 m², ≥ 0.5 m², ≥ 0.55 m², ≥ 0.7 m² or ≥ 0.8 m² and/or ≤ 1.4 m², ≤ 1.3 m² ≤ 1.2 m² or ≤ 1 m². For example, the or each pair of freezing plates may define an operating surface which has:

- a width that is ≥ 0.4 m, ≥ 0.5 , ≥ 0.6 m, ≥ 0.7 m, ≥ 0.8 m or ≥ 0.9 m and/or ≤ 1.6 m, ≤ 1.5 m, ≤ 1.2 m or less than 1.1 m; and/or
- a depth that is ≥ 0.5 m, ≥ 0.6 m and/or ≤ 1.1 m, ≤ 1 m or ≤ 0.9 m.

Such dimensions facilitate loading of the bags by an operator. The or each pair of freezing plates may be configured and/or dimensioned to simultaneously freeze ≥ 9 bags, ≥ 12 bags, ≥ 16 bags, ≥ 21 bags or ≥ 30 bags and/or ≤ 50 , ≤ 48 , ≤ 40 or ≤ 32 bags, notably 500 ml nominal volume bags. For example, the or each pair of freezing plates may be configured and/or dimensioned to simultaneously freeze 3, 4, 5, 6, 7 8 or 9 rows of bags arranged across its width with 3 or 4 bags in each row arranged along its depth, notably bags having a nominal volume of 500 ml. Particularly in the case of bags containing between 150 ml and 355 ml of medical liquid to be frozen, individual bags may be stacked one on another to form i) a first layer of bags, each bag in the first layer having a lower side which is in contact with the contact surface of a lower freezing plate of a pair of freezing plates and ii) a second layer of bags, each bag in the second layer having a lower side which sits on an upper side of a bag in the first layer of bags and an upper side which, in the freezing position, is in contact with the contact surface of an upper freezing plate of the pair of freezing plates. Preferably, each bag has an outlet from which the medical liquid will be extracted, and the outlet is arranged facing the rear of the shock freezer. The medical contact shock freezer of claim 1 is configured to simultaneously freeze at least 24 individual bags each containing between 230 ml and 270 ml of blood plasma from a temperature of 32°C to a temperature of -30 °C in a freezing time of less than 60 minutes, preferably less than 40 minutes.

[0011] Each of the first and second stage refrigerants is a non-CFC, non-HCFC, refrigerant. The use of CFCs (chlorofluorocarbons) and HCFCs (hydrochlorofluorocarbons) is undesirable, and in some cases banned, due to their greenhouse gas effect. Refrigerants having even less environmental impact than HFCs are preferred so that each of the first and second stage refrigerants is a non-CFC, non-HCFC, non-HFC refrigerant, specifically a hydrocarbon refrigerant.

[0012] The first stage refrigerant is R290 (propane). The use of R290 (propane) as the first stage refrigerant is selected notably for its refrigerant properties combined with its availability which particularly facilitates replacement of the first stage refrigerant if this becomes necessary.

[0013] The second stage refrigerant is R170 (ethane). The second stage refrigerant may include a small quantity, notably between 1 wt% and 5 wt%, of R601 (pentane); this facilitates the second stage oil return.

The use of R170 (ethane) as the second stage refrigerant is selected notably for its refrigerant properties combined with its availability which particularly facilitates replacement of the first stage refrigerant if this becomes necessary.

[0014] As used herein, reference to a refrigerant by its "R" number, for example R290 (propane) and R170 (ethane), means "refrigerant grades" of the materials i.e., grades (which are generally less than 100% pure) which are intended for and used for refrigeration applications. For example, each of R290 (propane) and R170 (ethane) preferably and generally has a purity of at least 97.5 %.

[0015] Although non-CFC, non-HCFC, non-HFC hydrocarbon refrigerants are flammable, the present invention allows the contact shock freezer to be configured using quantities of these refrigerants that are sufficiently small to mitigate any associated risk. Notably, the first stage refrigeration circuit comprises less than 400g, more preferably less than 300g and even more preferably less than 200g of the first stage refrigerant; and the second stage refrigeration circuit comprises less than 400g, more preferably less than 300g and even more preferably less than 200g of the second refrigerant. A contact shock freezer in which the first stage refrigerant is about 150g of R290 (propane) and the second stage refrigerant is about 150g of R170 (ethane) has been shown to be effective in allowing the freezing of 30 individual bags of 250 ml of blood plasma from 32 °C to -30 °C in under 40 minutes. Thus, according to another aspect, part of the present invention is based upon the realisation that an effective contact shock freezer can be configured using such refrigerants in advantageously small quantities.

[0016] The freezing plates may be configured to operate at a temperature which is $\leq -40^{\circ}\text{C}$, $\leq -45^{\circ}\text{C}$, $\leq -50^{\circ}\text{C}$ or $\leq -55^{\circ}\text{C}$. This provides rapid shock freezing. This operating temperature is preferably reached with 30 minutes, within 25 minutes or within 20 minutes of initial operation of the shock freezer. The freeze time required to attain a core temperature of the medical liquid in the bags of -30°C is preferably ≤ 60 minutes, ≤ 50 minutes or more preferably ≤ 45 minutes, notably when the freezing plates are fully loaded with bags to be frozen at an initial temperature of 20°C , notably bags each containing ≥ 200 ml or ≥ 250 ml and/or ≤ 1000 ml or ≤ 850 ml of blood plasma. Preferably, such a freezing performance is achieved with an initial temperature which is $\geq 25^{\circ}\text{C}$, $\geq 30^{\circ}\text{C}$ or $\geq 32^{\circ}\text{C}$ and/or $\leq 35^{\circ}\text{C}$. Preferably, each freezing plate is configured to operate at a temperature of about -60°C , notably within the range -55°C to -65°C , preferably within the range -58°C to -62°C ; this provides good efficiency and heat transfer.

[0017] The movement of the freezing plate(s) from the loading position to the freezing position is preferably a linear movement, notably a vertical linear movement, without rotation of either freezing plate. This facilitates accurate clamping of the plurality of bags between the plates. Preferably, the freezing plates are parallel in their freezing position and remain parallel during movement between the loading and the freezing position. This further facilitates accurate clamping of the plurality of bags. The use of parallel and preferably planer freezing plates is also advantageous when it is desired for the shock freezer to be useable in a configuration having two layers of bags arranged between a pair of freezing plates. Preferably, the angle of each freezing plate to the horizontal is fixed, that is to say this angle does not change; each freezing plate may be fixed in rotation so that it cannot rotate. At least one of the upper and lower freezing plates of a pair of freezing plates may be associated with a linear drive to affect its movement from the loading to the freezing position, for example one or more pneumatic or hydraulic cylinders, notably a pair of spaced cylinders, for example arranged at opposite sides of the freezing plate. The movement may be guided by a linear guide arrangement, for example comprising a linear guide arranged at each of the left and right sides of the freezing plate. Each linear guide may comprise a pair of, preferably vertical, tubular guide elements which together guide the movement.

[0018] The first pair of freezing plates may comprise an upper freezing plate and a lower freezing plate, with the upper freezing plate being arranged above the lower freezing plate. This provides a convenient arrangement, notably where each of the upper and lower freezing plates is horizontal or substantially horizontal, for example arranged at an angle of less than 30 ° to the horizontal.

[0019] The contact shock freezer may comprise a single pair of freezing plates. Alternately, the contact shock freezer may comprise two (and only two) pairs of freezing plates.

[0020] Preferably, one of the freezing plates of a pair of freezing plates is immobile and does not move during normal operation of the contact shock freezer with the other freezing plate of the pair being a moveable freezing plate; this provides a mechanically advantageous arrangement.

An arrangement in which the shock freezer comprises:

a first pair of upper and lower freezing plates and a second pair of upper and lower freezing plates, the first pair being arranged above the second pair;

in which the first pair of upper and lower freezing plates comprises an immobile lower freezing plate and a moveable upper freezing plate; and

in which the second pair of upper and lower freezing plates comprises an immobile upper freezing plate and a moveable lower freezing plate;

and notably in which the lower freezing plate of the first pair of freezing plates and the upper freezing plate of the second pair of freezing plates are provided by a single, integrated freezing plate, provides a compact and convenient arrangement for providing two pairs of freezing plates to enable simultaneous freezing of a large number of individual bags whilst minimising the footprint of the shock freezer and facilitating loading and unloading.

[0021] Thus, in one preferred arrangement, the contact shock freezer comprises two (and only two) pairs of freezing plates, comprising the first pair of freezing plates which comprises an upper freezing plate and a lower freezing plate, and

- a second pair of freezing plates, arranged as an upper freezing plate and a lower freezing plate, at least one of the freezing plates of the second pair of freezing plates being moveable between i) a loading position of the freezing plates in which sufficient separation is provided between the freezing plates to load or unload the individual bags between the freezing plates and ii) a freezing position in which the individual bags arranged between the freezing plates are clamped between the freezing plates;

and the contact shock freezer further comprises:

- a second refrigeration circuit configured to remove heat from the second pair of freezing plates to freeze the individual bags clamped between the second pair of freezing plates;

in which

- the second refrigeration circuit comprises a cascade refrigeration circuit comprising a first stage refrigeration circuit, a second stage refrigeration circuit and an inter-stage heat exchanger;
- the first stage refrigeration circuit being configured when in a refrigeration mode to circulate a first stage refrigerant, preferably a hydrocarbon refrigerant, notably R290 (propane), sequentially through a first stage compressor, a first stage condenser, a first stage capillary, the inter-stage heat exchanger and back to the first stage compressor so as to remove heat from the inter-stage heat exchanger and release heat to the environment via the first stage condenser; and
- the second stage refrigeration circuit being configured when in a refrigeration mode to circulate a second stage refrigerant, preferably a hydrocarbon refrigerant, notably R170 (ethane), sequentially through a second stage compressor, preferably a second stage desuperheater, the inter-stage heat exchanger, a second stage capillary, the second pair of freezing plates and back to the second compressor so as to remove heat from the second pair of freezing plates of the contact shock freezer and release heat to the inter-stage heat exchanger.

[0022] The first and second pair of freezing plates are preferably arranged with one pair above the other. In a particularly preferred arrangement, the lower freezing plate of the first pair of freezing plates and the upper freezing plate of the second pair of freezing plates are provided by a single, integrated and preferably immobile freezing plate.

[0023] Preferably, the first refrigeration circuit and the second refrigeration circuit are independently operable, that is to say, for example that one can be operated without the other. This enables each pair of the two pairs of freezing plates to be operated independently, for example in the event of the capacity of one pair of freezing plates being sufficient for the number of bags it is desired to freeze simultaneously.

[0024] Where independently operable first and second refrigeration circuit are provided, the components and configuration of each refrigeration circuit are preferably identical or substantially identical; this facilitates assembly and maintenance. Thus, the disclosure herein in relation to the components, configuration and arrangement of one of the refrigeration circuits applies equally to the equivalent components, configuration and arrangement of the other refrigeration circuit.

[0025] The first stage compressor and the second stage compressor are fully hermetic compressors having a power of less than 3 hp, preferably less than 2.5 hp, more preferably less than 2 hp. The use of fully hermetic compressors allows the selection of appropriate compressors which are smaller, simpler, more efficient and/or easier to replace than other types of compressors. This may be used, in addition, to reduce the operating noise of the

medical contact shock freezer.

[0026] The inter-stage heat exchanger is preferably thermally insulated to reduce heat influx from the surrounding environment. For example, the inter-stage heat exchanger may be enclosed within an insulated enclosure. Use of a multiple plate heat exchanger provides a robust arrangement which is suitable for the desired working temperatures. A multiple plate heat exchanger comprises a series of adjacently arranged, spaced parallel plates with the space between adjacent plates forming channels; the first stage and second stage refrigerants of the cascade refrigeration circuit flow through adjacent channels between the plates such that heat exchange occurs between the first stage and second stage refrigerants through the plates. An arrangement in which the first stage and second stage refrigerants cross the channels in series may be appropriate for the associated flow rate and heat exchange.

[0027] In accordance with another aspect, the present invention provides a method of fast freezing a plurality of individual bags containing a medical liquid as defined in claim 14.

[0028] In accordance with a further aspect, the present invention provides for use of a first refrigeration circuit comprising a cascade refrigeration circuit comprising a first stage refrigeration circuit, a second stage refrigeration circuit and an inter-stage heat exchanger for fast freezing a plurality of individual bags containing a medical liquid, particularly blood plasma, clamped between a pair of freezing plates. In the aforementioned use, the first stage refrigerant used in the first refrigeration circuit is a hydrocarbon refrigerant, specifically R290 (propane), and the second stage refrigerant used in the second stage refrigeration circuit is also a hydrocarbon refrigerant, specifically R170 (ethane).

[0029] Aspects disclosed herein in relation to one specific aspect of the invention may be used according to any other aspect to the invention.

[0030] An embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings, of which:

Fig 1 is a schematic rear view of a medical contact shock freezer;

Fig 2 is a schematic plan view of a cross-section through the medical shock freezer;

Fig 3 is a schematic circuit diagram of the first refrigeration circuit;

Fig 4 is a schematic cross-section through a freezing plate;

Fig 5 is a schematic view of an inter-stage heat exchanger; and

Fig 6 is a schematic circuit diagram of an alternative first refrigeration circuit.

[0031] The medical contact shock freezer 10 shown in Figs 1 and 2 comprises upper 11 and

lower 12 freezing plates of a first pair of freezing plates 101 and upper 13 and lower 14 freezing plates of a second pair of freezing plates 102, each pair of freezing plates having the same footprint (for example about 1 m wide by about 0.8 m deep) with the first pair of freezing plates 101 being arranged above the second pair of freezing plate 102 within the same footprint. The lower freezing plate 12 of the first pair of freezing plates and the upper freezing plate 13 of the second pair of freezing plates are provided by a single, immobile, integrated freezing plate. Each of the freezing plates 11, 12, 13, 14 is arranged at an angle of 5° to the horizontal sloping downwards from the rear of the contact shock freezer to the front.

[0032] Fig 1 shows the freezing plates 11, 12, 13,14 in their loading position in which sufficient separation is provided between the freezing plates of each pair to allow a heat conductive tray carrying individual bags of blood plasma (for example a heat conductive tray carrying fifteen individual bags, each containing 250 ml of blood plasma arranged in five rows in the width direction and three rows in the depth direction of the contact shock freezer) to be loaded between each pair of freezing plates prior to freezing. The loading position is also used during removal of the frozen plasma bags from between each pair of freezing plates subsequent to the freezing operation. In order to clamp the plasma bags between their respective freezing plates for the freezing operation, the moveable freezing plate 11 of the first pair of freezing plates it moved vertically, linearly downwardly by vertically arranged hydraulic cylinders to clamp plasma bags between the first pair of freezing plates and the moveable freezing plate 14 of the first pair of freezing plates is moved vertically, linearly upwards by vertically arranged hydraulic cylinders to clamp plasma bags between the second pair of freezing plate. These movements are reversed to move from the freezing position to the loading position.

[0033] A first cascade refrigeration circuit 15, when in a refrigeration mode, removes heat from the first pair of freezing plates 11, 12 to freeze the individual bags of blood plasma clamped between the first pair of freezing plates 101 and a second cascade refrigeration circuit 16, when in a refrigeration mode, removes heat from the second pair of freezing plates 102 to freeze the individual bags of blood plasma clamped between the second pair of freezing plates. The first 15 and second 16 cascade refrigeration circuits are independently operable so that each of the pairs of freezing plates can be operated independently of the other. Each of the refrigeration circuits is connected to its respective moveable freezing plates by flexible stainless-steel hoses of appropriate length. The components, and configuration of each of the individual refrigeration circuits 15,16 are preferably identical; consequently, only one of the refrigeration circuits 15 is described below.

[0034] Fig 3 illustrates the first refrigeration circuit 15 which comprises a cascade refrigeration circuit comprising a first stage refrigeration circuit S1, a second stage refrigeration circuit S2 and an inter-stage heat exchanger 17. In the configuration described below the first stage refrigerant is 150g of R290 (propane) and the second refrigerant is 150g of R170 (ethane). Operation during the refrigeration mode is described in the following paragraphs, the temperatures and pressures indicated being typical, order of magnitude values (given only by way of example) during stable operation during the refrigeration mode.

first stage refrigeration circuit S1

[0035] The R290 (propane) first stage refrigerant is sequentially:

- pressurized in a first stage compressor 18 from 2.5bar/10°C at the inlet to the first stage compressor 18 to 12bar/100°C at the outlet of the first stage compressor 18;
- cooled and condensed in a first stage condenser 19 (preferably a microchannel condenser) from 12bar/100°C to 12bar/30°C;
- passed through a filter dryer 20;
- expanded in a first stage capillary tube 21 from 12bar/30°C to 2.5bar/-15°C;
- transferred from the outlet of the first stage capillary tube 21 to an inlet of the inter-stage heat exchanger 17;
- passed through the inter-stage heat exchanger 17 during which it evaporates, thus cooling the second stage refrigerant (R170 (Ethane)) during its passage through the inter-stage heat exchanger 17, the R290 (propane) exiting the inter-stage heat exchanger 17 at 2.5bar/10°C; and
- transferred back the inlet of the first stage compressor 18.

[0036] In this example, and indeed in general, the first stage refrigerant preferably enters the inter-stage heat exchanger in a mixed liquid and gas phase and exits the inter-stage heat exchanger in a gas phase.

second stage refrigeration circuit S2

[0037] The R170 (ethane) second stage refrigerant is sequentially:

- pressurized in a second stage compressor 23 from 9bar/-10°C at the inlet to the second stage compressor 23 to 16.2bar/110°C at the outlet of the second stage compressor;
- freely cooled in a second stage desuperheater 24 from 16.2bar/110°C to 16.2bar/60°C;
- passed through a second stage anti-frost heat exchanger 25 where it is cooled from 16.2 bar/60°C to 16.2 bar/20°C;
- passed through the inter-stage heat-exchanger 17 causing it to be cooled and condensed from 16.2 bar/20°C to 16.2 bar/-15°C by thermal exchange with the first stage refrigerant (R290 (propane)) in the inter-stage heat-exchanger 17;
- passed through a filter/dryer 26;
- passed through a second stage capillary tube 27 where it is expanded from 16.2 bar/-15°C to 3.9 bar/-60°C;
- split in to two streams, one stream being fed through one of the freezing plates 11 of the refrigeration circuit and the other stream being fed through the other freezing plate 12 of the refrigeration circuit, passage of each stream through its respective freezing plate

causing evaporation of the R170 (ethane) second stage refrigerant and removing heat from its respective freezing plate to freeze the individual bags of plasma clamped between the freezing plates 11,12. The R170 (ethane) second stage refrigerant increases in temperature from 3.9 bar/-60°C at the inlet of the freezing plates to 3.9 bar/-40°C (in a gaseous state) at the outlet of the freezing plates;

- combined into a single stream which is fed through the second stage anti-frost heat exchanger 25 during which its temperature is increased from 3.9 bar/-40°C to 3.9 bar/-10°C; and
- transferred back to the inlet of the second stage compressor 23.

[0038] The following considerations apply in relation to the specific refrigeration circuits described above, and also more broadly in relation to other refrigeration circuits which are disclosed herein and/or are used in relation to the inventions disclosed herein:

- the first stage condenser preferably has an associated ventilation fan 19a which provides an airflow which contributes to dissipating heat from the first stage condenser to the environment. Such a ventilation fan is preferably a variable speed fan controlled by a control circuit of the contact shock freezer, for example based on an indication of the pressure of refrigerant in the first stage refrigeration circuit.
- it is preferred to include a desuperheater in the second stage refrigeration circuit, notably to improve efficiency. Nevertheless, the second stage refrigeration circuit may be designed to operate without a desuperheater. Where a desuperheater is included in the second stage refrigeration circuit, this is preferably arranged so that an airflow which is arranged to cool the condenser of the first stage refrigeration circuit, for example from a ventilation fan, also contributes to dissipating heat to the environment from the second stage desuperheater. This provides a compact and efficient arrangement. For example, a configuration in which ventilating air from a ventilation fan passes through the first stage condenser and subsequently through the second stage desuperheater so as the help dissipate heat from each of these components to the environment is advantageous. This may be achieved by arranging the second stage desuperheater adjacent to the first stage condenser so that ventilating air exiting the first stage condenser passes over the second stage desuperheater prior to being dissipated to the environment.
- a second stage anti-frost heat exchanger is preferably included in the second stage refrigeration circuit and is configured to: i) reduce the temperature of the second stage refrigerant fed from an outlet of the second stage compressor (or from an outlet of the second stage desuperheater when used) to the inlet of the inter-stage heat exchanger - this helps to reduce fatigue of the components of the inter-stage heat exchanger, notably the plates of a multi-plate heat exchanger when used; and ii) increase the temperature of the second stage refrigerant fed from an outlet of the freezing plates to an inlet of the second stage compressor
- this facilitates operation of the second stage compressor, notably by avoiding an undesirably low operating temperature of the second stage compressor and/or helping

- to optimise desired viscosity of oil used in the second stage compressor;
- the second stage refrigeration circuit preferably comprises an oil separator 28 arranged to separate lubrication oil from the stream of the second stage refrigeration exiting the second stage compressor and return this to the second stage compressor; such lubrication oil is desirable for operation of the second stage compressor but undesirable in the circulating stream of the second stage refrigerant;
- a control circuit is preferably arranged to control operation of the second stage refrigeration circuit and preferably comprises a second stage pressure switch 29;
- a control circuit is preferably arranged to control operation of the first stage refrigeration circuit and preferably comprises a first stage pressure switch 22.

[0039] Fig 4 is a schematic cross-section through a freezing plate 40 having a front edge 41, rear edge 42, left-hand edge 43 and right-hand edge 44 and which may be used as the upper freezing plate 11 of the first pair of freezing plates described above. A series of refrigerant baffles 45 arranged within the freezing plate 40 define a flow path for the second stage refrigerant (which in the illustrated example is a serpentine flow path) as it passes through the freezing plate between i) a first connecting orifice 46 for the second stage refrigerant which is situated at the front, left-hand corner of the freezing plate 40 and ii) a second connecting orifice 47 for the second stage refrigerant which is situated at the rear, left-hand corner of the freezing plate 40.

[0040] The following considerations apply in relation to the specific freezing plate 40 described above, and also more broadly in relation to other freezing plates which are disclosed herein and/or are used in relation to the inventions disclosed herein:

- the flow of the second stage refrigerant from an outlet from the inter-stage heat exchanger is preferably split into two streams with one of the streams being fed to an inlet of the first freezing plates of a pair of freezing plates and the other stream being fed to an inlet of the second freezing plate of the pair of freezing plates. This facilitates even freezing of each of the clamped surfaces of the individual bags containing a medical liquid by ensuring that each of the freezing plates of the pair of freezing plates receives a portion of the second stage refrigerant having substantially the same temperature.
- each of the freezing plates of the pair preferably comprises a refrigerant flow path for its associated portion of the second stage refrigerant, notably a refrigerant flow path defined within the freezing plate between a refrigerant inlet and a refrigerant outlet. The refrigerant flow path may be defined by one or more refrigerant baffles arranged within the freezing plate. A serpentine refrigerant flow path provides a suitable arrangement. The refrigerant inlet may be arranged at one corner of the freezing plate with the refrigerant outlet arranged at another corner of the freezing plate and the refrigerant flow path defining a passage for the second stage refrigerant between the refrigerant inlet and the refrigerant outlet, notably a passage which causes the second stage refrigerant to contact at least 90% of the surface area of the freezing plate as it passes between the refrigerant inlet and the refrigerant outlet;

- each freezing plate of a pair of freezing plates preferably has a corresponding refrigerant flow path, with the refrigerant flow path of the first freezing plates of the pair overlying the refrigerant flow path of the second freezing plate of the pair but with the position of the refrigerant inlets and outlets of the first and second freezing plates reversed so that i) the position of the refrigerant inlet of the first freezing plate corresponds to the position of the refrigerant outlet of the second freezing plate and ii) the position of the refrigerant outlet of the first refrigerant plate corresponding to the position of the refrigerant inlet of the second refrigerant plate. This creates an arrangement in which the flow direction of the second stage refrigerant in the first freezing plate is opposed to the flow direction of the second stage refrigerant in the second freezing plate. This facilitates even freezing of each of the individual bags containing a medical liquid clamped between the pair of freezing plates. For example, in an arrangement similar to that illustrated in Fig 4, where: i) each freezing plate of the pair has the same configuration and arrangement of refrigerant baffles 45 with 1st connecting orifice 46 at its front left corner and 2nd connecting orifice 47 at its rear left corner; the refrigerant inlet of the first freezing plate is arranged at 1st connecting orifice 46 at its front left corner and the refrigerant outlet is arranged at 2nd connecting orifice at its rear left corner so that the flow direction of the first freezing plate is from the inlet at the front left corner via the refrigerant flow path to the outlet at the rear left corner; and the refrigerant inlet of the second freezing plate is arranged at the 2nd connecting orifice 47 at its rear left corner and the refrigerant outlet is arranged at 1st connecting orifice 46 at its front left corner so that the flow direction of the refrigerant in the second freezing plate is from the inlet at the rear left corner via the refrigerant flow path to the outlet at the front left corner; then there will be an opposed flow direction of the refrigerant in each of the freezing plates. This facilitates even freezing of each of the bags containing a medical liquid which is clamped between the pair of freezing plates.

[0041] Each of the freezing plates may be provided with one or more electrical defrost heaters. For example, the freezing plate 40 of Fig 4 is provided with three electrical resistance defrost heaters 48a, 48b, 48c. When electrical defrost heaters are provided for the freezing plates it is advantageous for the number of electrical defrost heaters to be a multiple of 3; this facilitates equilibrating the electrical load between each phase of a three-phase supply. For example, one convenient configuration is to arrange three defrost heaters at each freezing plate, each of which is powered by a separate phase of a three-phase supply; this helps to equilibrate the load on the three-phase electrical supply by allowing the electrical resistance of the circuit of each of the three electrical phases to be similar or, preferably, the same.

[0042] The inter-stage heat exchanger may be multiplate heat exchanger, preferably a brazed plate multiplate heat exchanger, a preferred arrangement of which is illustrated in Fig 5. The multiplate heat exchanger 51 is preferably arranged within a heat insulated enclosure 52 containing the first stage capillary tube 21, the second stage filter/dryer 26 and the second

stage capillary tube 27; any free space may be filled with insulating foam, for example PUR foam. The outlet of the first stage capillary tube 21 is connected to a first stage inlet 53 of the multiplate heat exchanger 51 with a first stage outlet 54 of the multiplate heat exchanger 51 being connected to return the first stage refrigerant to the first stage compressor 18. A second stage inlet 55 of the inter-stage heat exchanger 17 is fed with second stage refrigerant from an outlet of the second stage compressor 23 (via the second stage desuperheater 24 and anti-frost heat exchanger 25). A second stage outlet 26 of the inter-stage heat exchanger 17 feeds the second stage refrigerant to the second stage capillary tube 27 via the filter/dryer 26.

[0043] Fig 6 illustrates an alternative arrangement in which defrosting of the freezing plates is provided by a first stage circuit reverser 61 and a second stage circuit reverser 62. In this case, electrical defrosting heaters are no longer required. The following considerations apply in relation to the specific refrigeration circuits described above, and also more broadly in relation to other refrigeration circuits which are disclosed herein and/or are used in relation to the inventions disclosed herein:

1. a) each of the first stage circuit reverser 61 and a second stage circuit reverser 62 may be provided by a four-way valve;
2. b) the first stage refrigeration circuit comprises a circuit reverser configured, when activated, to cause the first stage refrigeration circuit to switch from its refrigeration mode to a de-frosting mode in which the first stage refrigerant circuit is configured to provide heat to the inter-stage heat exchanger; and the second stage refrigeration circuit comprises a circuit reverser configured, when activated, to cause the second stage refrigeration circuit to switch from its refrigeration mode to a de-frosting mode in which the second stage refrigerant circuit is configured to provide heat to the first pair of freezing plates of the contact shock freezer;
3. c) the circuit reverser of the first stage refrigeration circuit may comprise a four way valve switchable between i) a refrigeration mode in which an outlet side of the first stage compressor is connected through the valve to the first stage condenser and ii) an inlet side of the first stage compressor is connected through the valve to the inter-stage heat exchanger and ii) a de-frosting mode in which the outlet side of the first stage compressor is connected through the valve to the inter-stage heat exchanger and the inlet side of the first stage compressor is connected through the valve to the first stage condenser; and the circuit reverser of the second stage refrigeration circuit comprises a four way valve switchable between i) a refrigeration mode in which an outlet side of the second stage compressor is connected through the valve to the inter-stage heat exchanger, optionally through the second stage desuperheater, and an inlet side of the second stage compressor is connected through the valve to the first pair of freezing plates and ii) a de-frosting mode in which the outlet side of the second stage compressor is connected through the valve to the first pair of freezing plates and the inlet side of the second stage compressor is connected through the valve to the inter-stage heat exchanger, optionally through the second stage desuperheater.

Reference numbers**[0044]**

- 10 medical contract shock freezer
- 11 upper freezing plate of first pair of freezing plates
- 12 lower freezing plate of a first pair of freezing plates
- 13 upper freezing plate of a second pair of freezing plates
- 14 lower freezing plate of a second pair of freezing plates
- 15 first cascade refrigeration circuit
- 16 second cascade refrigeration circuit
- 17 inter-stage heat exchanger
- 18 first stage compressor
- 19 first stage condenser
- 19a ventilation fan
- 20 filter dryer
- 21 first stage capillary tube
- 22 first stage pressure switch
- 23 second stage compressor
- 24 second stage desuperheater
- 25 second stage anti-frost heat exchanger
- 26 filter/dryer
- 27 second stage capillary tube
- 28

29	second stage oil separator
40	second stage pressure switch
41	freezing plate
42	front edge
43	rear edge
44	left-hand edge
45	right-hand edge
46	refrigerant baffles
47	1 st connecting orifice
48a	2 nd connecting orifice
48b	defrost heater
48c	defrost heater
51	defrost heater
52	multiplate heat exchanger
53	heat insulated enclosure
54	first stage inlet of inter-stage heat exchanger
55	first stage outlet of inter-stage heat exchanger
56	second stage inlet of inter-stage heat exchanger
61	second stage outlet of inter-stage heat exchanger
62	first stage circuit reverser
S1	second stage circuit reverser
S2	first stage refrigeration circuit

second stage refrigeration circuit

Reference numbers

[0045]

- 10 medical contract shock freezer
- 11 upper freezing plate of first pair of freezing plates
- 12 lower freezing plate of a first pair of freezing plates
- 13 upper freezing plate of a second pair of freezing plates
- 14 lower freezing plate of a second pair of freezing plates
- 15 first cascade refrigeration circuit
- 16 second cascade refrigeration circuit
- 17 inter-stage heat exchanger
- 18 first stage compressor
- 19 first stage condenser
- 19a ventilation fan
- 20 filter dryer
- 21 first stage capillary tube
- 22 first stage pressure switch
- 23 second stage compressor
- 24 second stage desuperheater
- 25 second stage anti-frost heat exchanger
- 26

	filter/dryer
27	second stage capillary tube
28	second stage oil separator
29	second stage pressure switch
40	freezing plate
41	front edge
42	rear edge
43	left-hand edge
44	right-hand edge
45	refrigerant baffles
46	1 st connecting orifice
47	2 nd connecting orifice
48a	defrost heater
48b	defrost heater
48c	defrost heater
51	multiplate heat exchanger
52	heat insulated enclosure
53	first stage inlet of inter-stage heat exchanger
54	first stage outlet of inter-stage heat exchanger
55	second stage inlet of inter-stage heat exchanger
56	second stage outlet of inter-stage heat exchanger
61	first stage circuit reverser
62	

- S1 second stage circuit reverser
first stage refrigeration circuit
- S2 second stage refrigeration circuit

REFERENCES CITED IN THE DESCRIPTION

Cited references

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PATENTKRAV

1. Medicinsk kontaktlynfryser (10) indrettet til hurtig indfrysning af en flerhed af enkeltposer indeholdende blodplasma, hvilken medicinsk kontaktlynfryser omfatter:

5 - et første par (11, 12) fryseplader, hvor i det mindste en af frysepladerne af det første par fryseplader kan bevæges mellem i) en indlæggeposition for frysepladerne, i hvilken der er tilvejebragt tilstrækkelig adskillelse mellem frysepladerne til at indlægge og udtage enkeltposerne mellem frysepladerne, og ii) en fryseposition, i hvilken de mellem frysepladerne anbragte enkeltposer er klemt
10 fast mellem frysepladerne; og

- et første kølekredsløb (15), der er konfigureret til, i en køletilstand, at bortlede varme fra det første par fryseplader for at indfryse de mellem det første par fryseplader fastklemte enkeltposer;

hvor

15 - det første kølekredsløb omfatter et kaskadekølekredsløb omfattende et førstetrins-kølekredsløb (S1), et andettrins-kølekredsløb (S2) og en mellemtrins-varmeveksler (17);

- førstetrins-kølekredsløbet er konfigureret til, i en køletilstand, at cirkulere et førstetrins-kølemiddel sekventielt gennem en førstetrins-kompressor (18), en
20 førstetrins-kondensator (19), et førstetrins-kapillarrør (21), mellemtrins-varmeveksleren og tilbage til førstetrins-kompressoren for at bortlede varme fra mellemtrins-varmeveksleren og afgive varme til omgivelserne via førstetrins-kondensatoren; og

- andettrins-kølekredsløbet er konfigureret til, i en køletilstand, at cirkulere et
25 andettrins-kølemiddel sekventielt gennem en andettrins-kompressor (23), fortrinsvis en andettrins-desuperheater (24), mellemtrins-varmeveksleren, et andettrins-kapillarrør (27), det første par fryseplader og tilbage til den anden kompressor for at bortlede varme fra det første par fryseplader i kontaktlynfryseren og afgive varme til mellemtrins-varmeveksleren;

hvor

den medicinske kontaktlynfryser er konfigureret til på samme tid at indfryse i det mindste 24 enkeltposer, der hver indeholder mellem 230 ml og 270 ml blodplasma, fra en temperatur på 32 °C til en temperatur på -30 °C inden
5 for en indfrysningstid på under 60 minutter, fortrinsvis under 40 minutter, hvor:

- førstetrins-kølemidlet er propan af kølemiddelkvalitet, og det første kølemiddelkredsløb omfatter mellem 100 g og 400 g af førstetrins-kølemidlet;

- førstetrins-kompressoren er en fuldt ud lufttæt kompressor, fortrinsvis med en udgangseffekt på mellem 1 hk og 3 hk;

10 - temperaturen af førstetrins-kølemidlet i førstetrins-kølekredsløbet har en minimumdriftstemperatur på mellem -25 °C og -5 °C og en maksimumdriftstemperatur på mellem 90 °C og 110 °C;

- andettrins-kølemidlet er ethan af kølemiddelkvalitet, og det andet kølemiddelkredsløb omfatter mellem 100 g og 400 g af andettrins-kølemidlet;

15 - andettrins-kompressoren er en fuldt ud lufttæt kompressor, fortrinsvis med en udgangseffekt på mellem 1 hk og 3 hk;

- temperaturen af det andet kølemiddel i det andet kølekredsløb har en minimumdriftstemperatur på mellem -70 °C og -50 °C og en maksimumdriftstemperatur på mellem 100 °C og 110 °C;

20 - og hvor andettrins-kølekredsløbet fortrinsvis omfatter en frostsikker varmeveksler (25), der er konfigureret til at overføre varme til andettrins-kølemidlet opstrøms for andettrins-kompressoren fra et andet afsnit af andettrins-kølekredsløbet, så andettrins-kølemidlets driftstemperatur ved dets indtræden i andettrins-kompressoren er på mellem -20 °C og 0 °C.

25 2. Medicinsk kontaktlynfryser ifølge krav 1, hvor lynfryseren yderligere omfatter:

- et andet par (13, 14) fryseplader, hvor i det mindste en af frysepladerne af det andet par fryseplader kan bevæges mellem i) en indlæggposition for

frysepladerne, i hvilken der er tilvejebragt tilstrækkelig adskillelse mellem frysepladerne til at indlægge eller udtage enkeltposerne mellem frysepladerne, og ii) en fryseposition, i hvilken de mellem frysepladerne anbragte enkeltposer er klemt fast mellem frysepladerne; og

- 5 - et andet kølekredsløb (16), der er konfigureret til at bortlede varme fra det andet par fryseplader for at indfryse de mellem det andet par fryseplader fastklemte enkeltposer;

hvor

- 10 - det andet kølekredsløb omfatter et kaskadekølekredsløb omfattende et førstetrins-kølekredsløb, et andettrins-kølekredsløb og en mellemtrins-varmeveksler;
- førstetrins-kølekredsløbet er konfigureret til, i en køletilstand, at cirkulere et førstetrins-kølemiddel, fortrinsvis et kulbrinte-kølemiddel, sekventielt gennem en førstetrins-kompressor, en førstetrins-kondensator, et førstetrins-kapillarrør,
- 15 mellemtrins-varmeveksleren og tilbage til førstetrins-kompressoren for at bortlede varme fra mellemtrins-varmeveksleren og afgive varme til omgivelserne via førstetrins-kondensatoren; og
- andettrins-kølekredsløbet er konfigureret til, i en køletilstand, at cirkulere et andettrins-kølemiddel, fortrinsvis et kulbrinte-kølemiddel, sekventielt gennem en
- 20 andettrins-kompressor, fortrinsvis en andettrins-desuperheater, mellemtrins-varmeveksleren, et andettrins-kapillarrør, det andet par fryseplader og tilbage til den anden kompressor for at bortlede varme fra det andet par fryseplader i kontaktlynfryseren og afgive varme til mellemtrins-varmeveksleren;

- 25 og hvor det første kølekredsløb og det andet kølekredsløb kan drives uafhængigt af hinanden.

3. Medicinsk kontaktlynfryser ifølge krav 1 eller krav 2, hvor den medicinske kontaktlynfryser er konfigureret på en sådan måde, at hver fryseplade, i køletilstanden, er konfigureret til at fungere ved en temperatur på mellem $-55\text{ }^{\circ}\text{C}$ og $-65\text{ }^{\circ}\text{C}$, fortrinsvis mellem $-58\text{ }^{\circ}\text{C}$ og $-62\text{ }^{\circ}\text{C}$.

4. Medicinsk kontaktlynfryser ifølge et hvilket som helst af de foregående krav, hvor mellemtrins-varmeveksleren omfatter en varmeisoleret flerplade-varmeveksler (51).

5. Medicinsk kontaktlynfryser ifølge et hvilket som helst af de foregående krav, hvor andettrins-kølekredsløbet omfatter en frostsikker varmeveksler, der er konfigureret til at overføre varme til andettrins-kølemidlet opstrøms for andettrins-kompressoren fra et andet afsnit af andettrins-kølekredsløbet.

6. Medicinsk kontaktlynfryser ifølge et hvilket som helst af de foregående krav, hvor:

10 - andettrins-kølekredsløbet omfatter:

i) et første fryseplade-kredsløbsafsnit, gennem hvilket andettrins-kølemidlet strømmer for at bortlede varme fra den første fryseplade (11) af det første par fryseplader, hvor det første fryseplade-kredsløbsafsnit går gennem den første fryseplade af det første par fryseplader; og

15 i) et andet fryseplade-kredsløbsafsnit, gennem hvilket andettrins-kølemidlet strømmer for at bortlede varme fra den anden fryseplade (12) af det første par fryseplader, hvor det andet fryseplade-kredsløbsafsnit går gennem den anden fryseplade af det første par fryseplader.

7. Medicinsk kontaktlynfryser ifølge krav 6, hvor andettrins-kølemidlet, inden det løber gennem frysepladerne af det første par fryseplader, opdeles i første og andre strømme af kølemiddel, hvor den første strøm af kølemiddel tilføres gennem det første fryseplade-kredsløbsafsnit, og den anden strøm af kølemiddel tilføres gennem det andet fryseplade-kredsløbsafsnit.

8. Medicinsk kontaktlynfryser ifølge et hvilket som helst af de foregående krav, hvor:

- andettrins-kølekredsløbet omfatter:

i) et første fryseplade-kredsløbsafsnit, gennem hvilket andettrins-kølemidlet strømmer i en første fryseplade-strømningsretning for at bortlede varme fra den første fryseplade af det første par fryseplader;

ii) et andet fryseplade-kredsløbsafsnit, gennem hvilket andettrins-kølemidlet strømmer i en anden fryseplade-strømningsretning for at bortlede varme fra den anden fryseplade af det første par fryseplader;

og hvor den første fryseplade-strømningsretning og den anden fryseplade-strømningsretning er modsat hinanden.

9. Medicinsk kontaktlynfryser ifølge et hvilket som helst af de foregående krav, hvor hver af frysepladerne er forsynet med en eller flere elektriske afrimningsvarmelegemer (48a, 48b, 48c).

10. Medicinsk kontaktlynfryser ifølge et hvilket som helst af de foregående krav, hvor

- førstetrins-kølekredsløbet omfatter en kredsløbsskifter (61), der er konfigureret til, når den er aktiveret, at få førstetrins-kølekredsløbet til at skifte fra sin køletilstand til en afrimningstilstand, i hvilken førstetrins-kølemiddelkredsløbet er konfigureret til at levere varme til mellemtrins-varmeveksleren; og

- andettrins-kølekredsløbet omfatter en kredsløbsskifter (62), der er konfigureret til, når den er aktiveret, at få andettrins-kølekredsløbet til at skifte fra sin køletilstand til en afrimningstilstand, i hvilken andettrins-kølemiddelkredsløbet er konfigureret til at levere varme til det første par fryseplader i kontaktlynfryseren.

11. Medicinsk kontaktlynfryser ifølge krav 10, hvor:

- førstetrins-kølekredsløbets kredsløbsskifter omfatter en firevejsventil, der kan omstilles mellem i) en køletilstand, i hvilken en udløbsside af førstetrins-kompressoren er forbundet til førstetrins-kondensatoren via ventilen, og en indløbsside af førstetrins-kompressoren er forbundet til mellemtrins-varmeveksleren via ventilen, og ii) en afrimningstilstand, i hvilken førstetrins-kompressorens udløbsside er forbundet til mellemtrins-varmeveksleren via

ventilen, og førstetrins-kompressorens indløbsside er forbundet til førstetrins-kondensatoren via ventilen; og

- andettrins-kølekredsløbets kredsløbsskifter omfatter en firevejsventil, der kan omstilles mellem i) en køletilstand, i hvilken en udløbsside af andettrins-kompressoren er forbundet til mellemtrins-varmeveksleren via ventilen, eventuelt 5 via andettrins-desuperheateren, og en indløbsside af andettrins-kompressoren er forbundet til det første par fryseplader via ventilen, og ii) en afrimningstilstand, i hvilken andettrins-kompressorens udløbsside er forbundet til det første par fryseplader via ventilen, og andettrins-kompressorens indløbsside er forbundet til 10 mellemtrins-varmeveksleren via ventilen, eventuelt via andettrins-desuperheateren.

12. Medicinsk kontaktlynfryser ifølge et hvilket som helst af de foregående krav, hvor hvert par fryseplader er anbragt i en vinkel på under 30° i forhold til horisontalt plan, fortrinsvis i en vinkel på mellem 2° og 10° i forhold til horisontalt plan.

- 15 13. Medicinsk kontaktlynfryser ifølge et hvilket som helst af de foregående krav, hvor hvert par fryseplader omfatter en fikseret fryseplade og en bevægelig fryseplade, og hvor hvert par frysepladers bevægelse mellem indlægge- og frysepositionen består af en lineær, vertikal forskydning af de bevægelige fryseplader.

- 14. Fremgangsmåde til hurtig indfrysning af en flerhed af enkeltposer 20 indeholdende en medicinsk væske, især blodplasma, hvilken fremgangsmåde omfatter:

- a) tilvejebringelse af en medicinsk kontaktlynfryser ifølge et hvilket som helst af de foregående krav;
- b) fastklemning af flerheden af enkeltposer indeholdende den medicinske 25 væske mellem det første par fryseplader; og;
- c) drift af det første kølekredsløb i dets køletilstand for at bortlede varme fra det første par fryseplader for at indfryse den medicinske væske, der er indeholdt i de mellem det første par fryseplader anbragte enkeltposer.

DRAWINGS

Drawing

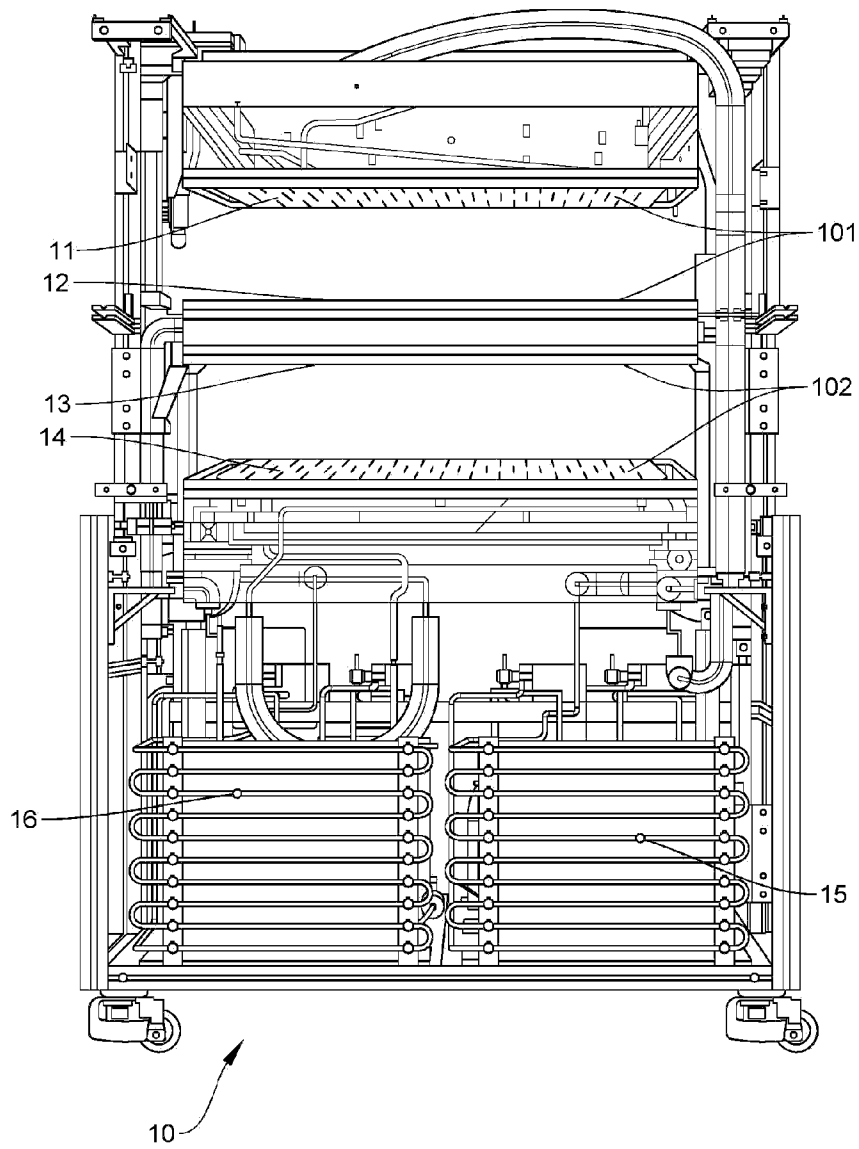


FIG. 1

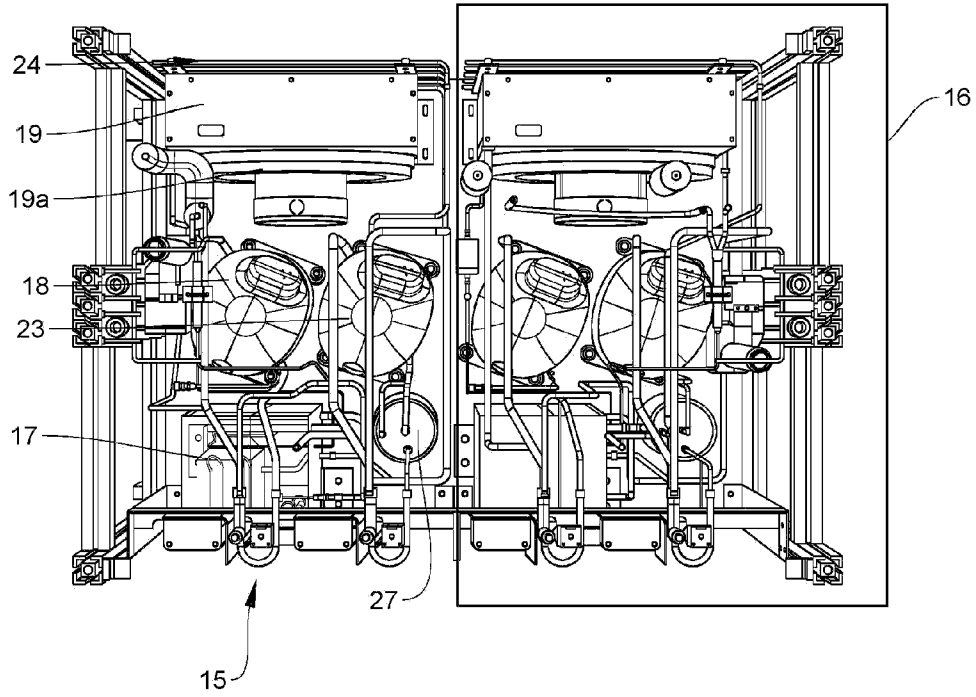


FIG. 2

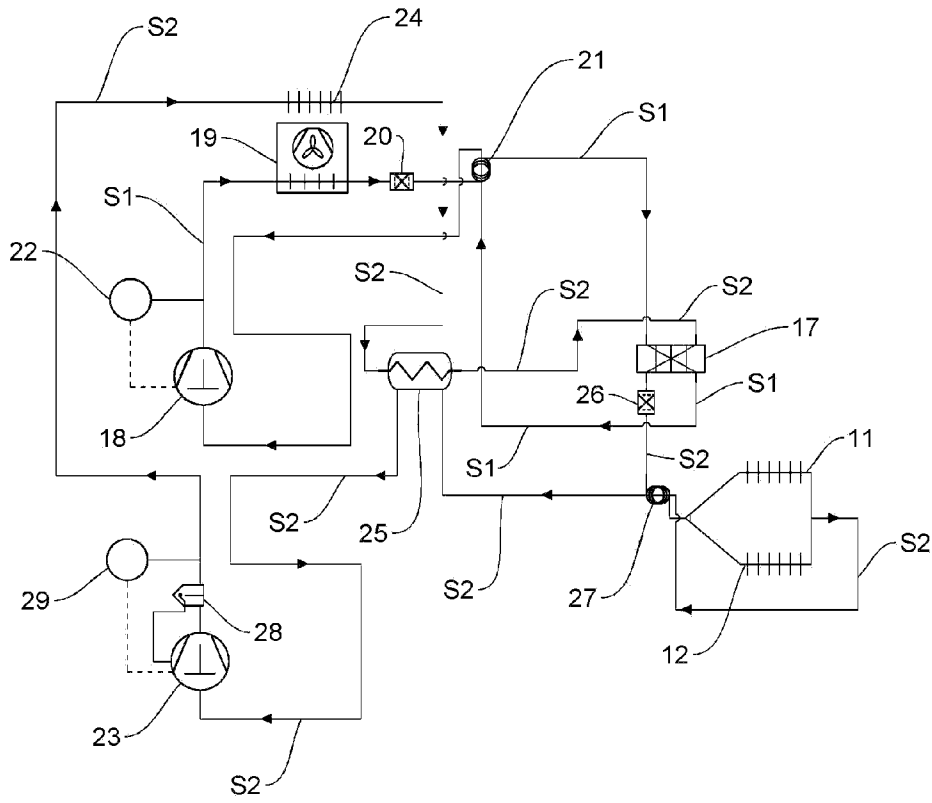


FIG. 3

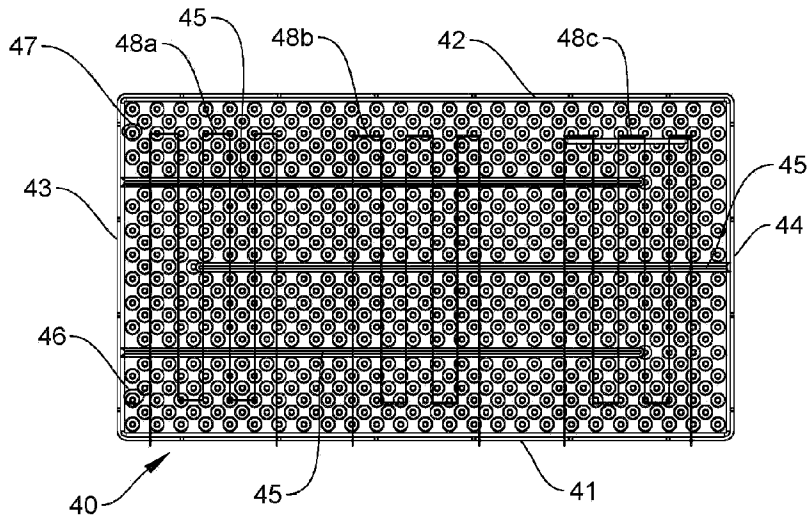


FIG. 4

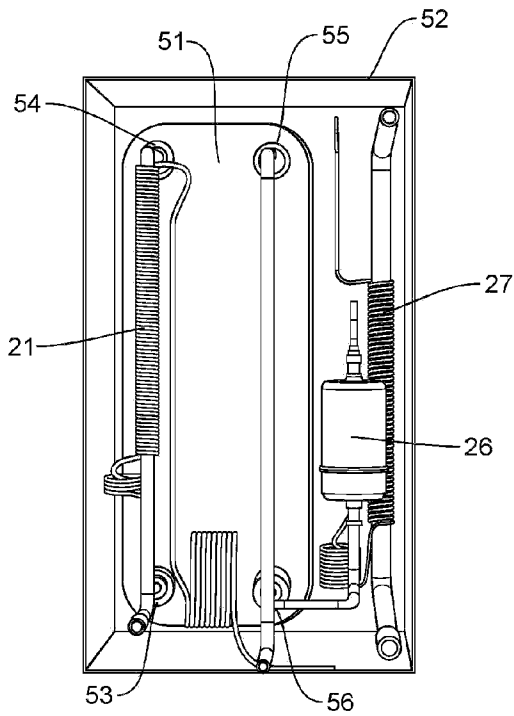


FIG. 5

