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(54) ## CENTRALIZED COOLING CIRCUIT

(57) One aspect of the present disclosure relates to an analysis system for analyzing biological samples comprises a plurality of compartments (2a,2b,2c), a plurality of compartment cooling circuits (3a,3b,3c), each of the plurality of compartment cooling circuits being configured to cool at least one of the plurality of compartments, a main cooling circuit (1) separate from the one or more compartment cooling circuits, the main cooling circuit (1) including a refrigeration device (10-13) and a cold storage (4), the main cooling circuit being coupled to the cold storage and configured to cool the cold storage and the one or more compartment cooling circuits being coupled to the cold storage and being configured to transfer heat from the plurality of compartments into the cold storage to cool the plurality of compartments.

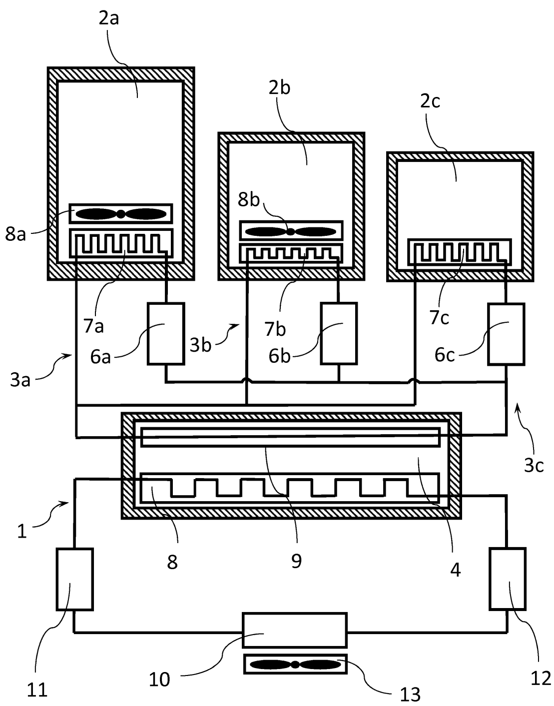

Figure 2

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Description

Technical Field

[0001] This disclosure relates to analysis systems including a centralized cooling circuit and methods for centralized cooling of an analysis system for analyzing biological samples.

Background

[0002] Some analysis systems for analyzing biological samples (e.g., samples including blood) include a plurality of compartments having different functions. For instance, the biological samples or reagents used in the analysis process can be stored in particular compartments. Other compartments can be configured so that different steps of analyzing the samples can take place in the particular compartments. In some situations these compartments have to be cooled to a predetermined temperature or be kept below a predetermined temperature. In known analysis systems, this cooling can be performed by Peltier cooling elements arranged in the respective compartments to be cooled. For instance, each compartment of the analysis system can be equipped with one or more Peltier elements to cool the respective compartment.

[0003] However, Peltier cooling elements can be expensive (in particular if a comparatively large cooling power is required) and can require a large amount of energy to deliver a certain amount of cooling power in some examples. In addition, there can be issues with managing condensed water that may form on the cool surfaces of the Peltier cooling elements or attached heat converters within the compartments.

Summary

[0004] In one general aspect of the present disclosure an analysis system for analyzing biological samples includes a plurality of compartments, a plurality of compartment cooling circuits, each of the plurality of compartment cooling circuits being configured to cool at least one of the plurality of compartments, a main cooling circuit separate from the one or more compartment cooling circuits, the main cooling circuit including a refrigeration device and the analysis system further including a cold storage, the main cooling circuit being coupled to the cold storage and configured to cool the cold storage, the one or more compartment cooling circuits being coupled to the cold storage and being configured to transfer heat from the plurality of compartments into the cold storage to cool the plurality of compartments.

[0005] The analysis system for analyzing biological samples of the first general aspect can have one or more of the following advantages.

[0006] Firstly, the cooling device of the analysis system of the first general aspect can be more energy efficient than the cooling devices of some prior art analysis systems. For instance, some cooling devices including Peltier elements can be comparatively inefficient (in particular if the compartment to be cooled is comparatively large). In the analysis system of the first general aspect the refrigeration device can cool the cold storage and therefore can be operated at a relatively energy-efficient working point while the compartment cooling circuits can deposit heat into the cold storage relatively independently from the operation of the separate main cooling circuit. It is not required that the main cooling circuit follows a consumption curve of the compartment cooling devices immediately as in some prior art cooling systems for analysis systems.

[0007] Secondly, the main cooling circuit can in some examples include relatively energy-efficient refrigeration devices (e.g., a cyclic refrigeration device and in particular vapor-compression refrigeration devices). These refrigeration devices can be more energy-efficient than Peltier refrigeration devices used in some analysis systems for analyzing biological samples.

[0008] Thirdly, the analysis system of the first general aspect can be relatively easily scalable in some examples. The refrigeration device of the main cooling circuit and a capacity of the cold storage can be adapted to varying required cooling powers (e.g., to cool a larger or smaller number of compartments and/or compartments of different sizes included in the analysis system).

[0009] Fourthly, the cooling of the compartments can be controlled relatively easily in some examples of the analysis system of the first general aspect. For instance, an amount of heat deposited into the cold storage by the plurality of compartment cooling circuits can be estimated and the main cooling circuit can be controlled in response to this estimate. This can also contribute to make the cooling system scalable as a larger number of compartments might not require a more complex control scheme in some examples.

[0010] Fifthly, the analysis system of the first general aspects can supersede Peltier cooling elements. This can be advantageous to reduce the impact of condense water which condenses at the Peltier cooling elements in some known analysis systems.

[0011] An 'analysis system' as used herein comprises a control unit operatively coupled to one or more analytical; pre- and post-analytical work cells wherein the control unit is operable to control the work cells. In addition, the control unit may be operable to evaluate and/or process gathered analysis data, to control the loading, storing and/or unloading of samples to and/or from any one of the analyzers, to initialize an analysis or hardware or software operations of the analysis system used for preparing the samples, sample tubes or reagents for said analysis and the like.

[0012] A compartment according to the present disclosure can be included partly or completely as a unit or module in any of an analytical, a pre- or post-analytical work cell or may be shared by any of an analytical, a preor post-analytical work cell. According to other embodiments, any one or more of an analytical, a pre- or post-analytical work cell can be included partly or completely in a compartment. The atmosphere and temperature inside the compartment can be controlled or regulated. The term 'analyzer' / 'analytical work cell' as used herein encompasses any apparatus or apparatus component that can induce a reaction of a biological sample with a reagent for obtaining a measurement value.

[0013] An analyzer is operable to determine via various chemical, biological, physical, optical or other technical procedures a parameter value of the sample or a component thereof. An analyzer may be operable to measure said parameter of the sample or of at least one analyte and return the obtained measurement value. The list of possible analysis results returned by the analyzer comprises, without limitation, concentrations of the analyte in the sample, a qualitative result indicating the existence of the analyte in the sample (corresponding to a concentration above the detection level), optical parameters, nucleic acid sequences, data obtained from mass spectroscopy of proteins or metabolites and physical or chemical parameters of various types. An analytical work cell may comprise units for the pipetting, dosing, and mixing of samples and/or reagents. The analyzer may comprise a reagent holding unit for holding reagents to perform the assays. Reagents may be arranged for example in the form of containers or cassettes containing individual reagents or group of reagents, placed in appropriate receptacles or positions within a storage compartment or conveyor. The analyzer may comprise a consumable feeding unit. The analyzer may comprise a process and detection system whose workflow is optimized for certain types of analysis. Examples of such analyzer are clinical chemistry analyzers, coagulation chemistry analyzers, immunochemistry analyzers, urine analyzers, nucleic acid analyzers, used to detect the result of chemical or biological reactions or to monitor the progress of chemical or biological reactions.

[0014] The term 'biological sample' refers to material(s) that may potentially contain an analyte of interest. The sample can be derived from any biological source, such as a physiological fluid, including blood, saliva, ocular lens fluid, cerebrospinal fluid, sweat, urine, stool, semen, milk, ascites fluid, mucous, synovial fluid, peritoneal fluid, amniotic fluid, tissue, cultured cells, or the like. The sample can be pretreated prior to use, such as preparing plasma from blood, diluting viscous fluids, lysis or the like. Methods of treatment can involve filtration, distillation, concentration, inactivation of interfering components, and the addition of reagents. A sample may be used directly as obtained from the source or used following a pretreatment to modify the character of the sample. In some embodiments, an initially solid or semi-solid biological material can be rendered liquid by dissolving or suspending it with a suitable liquid medium. In some embodiments, the sample can be suspected to contain a certain antigen or nucleic acid. Samples and biological samples can be stored in compartments in an analysis system. The atmosphere and temperature inside the storage compartments can be controlled or regulated.

Description of the Drawings

[0015]

FIG. 1 illustrates how heat is transported in an example analysis system according to the present disclosure.

FIG. 2 shows a schematic drawing of an example analysis system for analyzing biological samples according to the present disclosure.

FIG. 3 illustrates another state of operation of the example analysis system of FIG. 1 in which the main cooling circuit is switched off.

FIG. 4 illustrates another state of operation of the example analysis system of FIG. 1 in which the compartment cooling circuits are switched off.

FIG. 5 illustrates another state of operation of the example analysis system of FIG. 1 in which different compartments are cooled to different temperature levels.

FIG. 6 illustrates another state of operation of the example analysis system of FIG. 1 in which the compartment cooling circuits are switched so that only a prioritized compartment is cooled.

Detailed Description

[0016] In the following detailed description different aspects of the analysis systems including a centralized cooling circuit and of the methods for centralized cooling of an analysis system for analyzing biological samples according to the present disclosure will be discussed in more detail. Firstly, different aspect of a method for centralized cooling of an analysis system will be discussed in connection with **FIG. 1**. Different components of an analysis system including a centralized cooling system will be discussed in connection with **FIG. 2.** Subsequently, different particular aspects of methods to cool compartments of an analysis system with a centralized cooling circuit will be discussed in connection with **FIG. 3** to **FIG. 6.**

[0017] **FIG. 1** depicts an analysis system for analyzing biological samples comprises a plurality of compartments 2a, 2b, 2c, a plurality of compartment cooling circuits 3a, 3b, 3c, each of the plurality of compartment cooling circuits being configured to cool at least one of the plurality of compartments, a main cooling circuit 1 separate from the one or more compartment cooling circuits 3a, 3b, 3c, the main cooling circuit 1 including a refrigeration device and a cold storage 4, the main cooling circuit 1 being coupled to the cold storage 4 and configured to cool the cold storage 4 and the one or more compartment cooling circuits 3a, 3b, 3c being coupled to the cold storage 4 and being configured to transfer heat from the plurality of compartments 2a, 2b, 2c into the cold storage 4 to cool the plurality of compartments 2a, 2b, 2c.

[0018] The above discussed components can operate in the following manner: The main cooling circuit 1 can cool the cold storage 4. Independently of this operation of the main cooling circuit 1 the plurality of compartment cooling circuits 3a, 3b, 3c can deposit heat into the cold storage 4 to cool the plurality of compartments 2a, 2b, 2c.

[0019] In **FIG. 1** and the other figures the transfer of cooling energy is illustrated by arrows with a snowflake whereas the transfer of heat energy is illustrated by arrows with the symbol for heat. In the same manner, an arrow with a snowflake over a line of a cooling circuit indicates that cooled coolant agent is transported in the direction of the arrow. Accordingly, an arrow with a symbol for heat indicates that heated cooling agent is transported in this direction. It is understood that the "transfer of cooling energy" physically corresponds to a transfer of heat in the opposite direction. In other words, a transfer of cooling energy into a particular region or to a particular component actually is a transfer of heat away from the respective region or component (this is illustrated in some figures by arrows in opposite directions). Along the same line, storing of cooling energy corresponds to cooling a substance with a certain (sometimes comparatively large) heat capacity to a temperature below a temperature of a region to be cooled. In addition or alternatively, cooling energy can be stored by exploiting latent energies of aggregate phase changes of cooling agents or cold storage agents. Having in mind the above said, the picture of "cooling energy" is used in several instances of the present application for the sake of illustration.

[0020] The operation of the example centralized cooling circuit of **FIG. 1** will now be explained in more detail. As can be seen in **FIG. 1**, the cold storage 4 operates as a buffer for cooling energy (indicated by the snowflakes in **FIG. 1**). In other words, the cold storage 4 provides a cold reservoir into which the compartment cooling circuits 3a, 3b, 3c can deposit heat (i.e., from which the compartment cooling circuits 3a, 3b, 3c can extract cooling energy) to cool the respective compartments 2a, 2b, 2c. In order to fulfill this function, the cold storage can have a predetermined heat capacity which can be larger than the heat capacity of air at room temperature and ambient pressure at see level of the same volume (e.g., five times larger than air at ambient temperature and at sea level at the same volume). In addition, a size of the cold storage can be selected to provide for a predetermined heat capacity. In one example, the main cooling circuit 1 can change an aggregate state of a cold storage agent in the cold storage to deposit cooling energy in the cold storage 4.

[0021] The deposition of cooling energy into the cold storage can happen independently of the removal of cooling energy from the cold storage 4 by the compartment cooling circuits 3a, 3b, 3c. The main cooling circuit 1 and the compartment cooling circuits 3a, 3b, 3c form separate cooling circuits which can be controlled independently.

[0022] For example, the main cooling circuit 1 can cool down the cold storage 4 for a predetermined time when the cooling system is put into use (i.e., the main cooling circuit 1 can deposit a predetermined amount of cooling energy into the cold storage). After the main cooling circuit 1 has stored a predetermined amount of cooling energy in the cold storage 4, the compartment cooling circuits 3a, 3b. 3c can start to deposit heat into the cold storage 4.

[0023] In addition or alternatively, the main cooling circuit 1 can cool the cold storage intermittently while the compartment cooling circuits 3a, 3b, 3c continuously deposit heat into the cold storage. In this manner, the main cooling circuit 1 can be operated in a favorable mode of operation (e.g., in a comparatively energy efficient mode of operation). In some systems without a cold storage the cooling systems have to react instantly to cooling requirements of the different compartments, which can require operation in comparatively inefficient modes of operation. For example, operation of the cooling devices with relatively low output power can be required in some situations.

[0024] Furthermore, each compartment cooling circuit 3a, 3b, 3c can be controlled to extract a predetermined amount of cooling energy from the cold storage 4 in response to the particular requirement of a compartment 2a, 2b, 2c the respective compartment cooling circuit 3a, 3b, 3c is associated with.

[0025] However, as will be discussed below, the main cooling circuit 1 and the compartment cooling circuits 3a, 3b, 3c can also be controlled jointly to fulfill cooling tasks of the centralized cooling system.

[0026] After having explained the general mode of operation of the centralized cooling circuit of the present disclosure the components of an example centralized cooling circuit of an analysis system will subsequently be discussed in more detail in connection with **FIG. 2.**

[0027] The analysis system includes a refrigeration device. In one example, the refrigeration device is a cyclic refrigeration device. For instance, the cyclic refrigeration device can include a vapor cycle or a gas cycle. Even though the example of **FIG. 2** shows a single refrigeration cycle, the main cooling circuit can in other embodiments contain multiple cooling cycles. The multiple cooling cycles can be arranged in parallel or in serial, or in a combination of both configurations.

[0028] In the example of **FIG. 2** the refrigeration device of the main cooling circuits includes an expansion valve 12, an evaporator 9, a compressor 11, and a condenser 10 with a fan 13. The refrigeration device can also include more than one of these components. A coolant circulates in the main cooling circuit 1 and removes heat from the cold storage 4 when the main cooling circuit 1 operates.

[0029] In one example, the circulating coolant enters the compressor 11 as a vapor. The vapor is compressed at constant entropy and exits the compressor in a superheated state. The superheated vapor travels through the condenser 10 which first cools and removes the superheat and then condenses the vapor into a liquid by removing additional heat at constant pressure and temperature. Thus, a particular amount of heat is removed from the coolant and released in the ambient atmosphere at the condenser 10. The main cooling circuit 1 of FIG. 2 includes an optional fan 13 to support this process. The liquid coolant goes through the expansion valve 12 where its pressure abruptly decreases, causing flash evaporation and autorefrigeration of some portion of the liquid.

[0030] That results in a mixture of liquid and vapor at a lower temperature and pressure. The cold liquid-vapor mixture then travels through the evaporator 9 (which can include one or more coils or tubes) and is completely vaporized by cooling the warmer cold storage agent (in the cold storage 4). In this manner, the main cooling circuit 1 can deposit cooling energy into the cold storage 4. The resulting refrigerant vapor returns to the compressor 11 to complete the thermodynamic cycle.

[0031] Different optional aspects of the cold storage 4 will be discussed subsequently. In **FIG. 2** the cold storage 4 is depicted as a single box to which the main cooling circuit 1 and all compartment cooling circuits 3a, 3b, 3c are coupled. However, in other examples the centralized cooling system of the present disclosure can include two or more cold storages. For example, the two or more cold storages can be associated with different groups of compartments of the analysis system. In still other examples, two or more main cooling circuits can cool two or more cold storages.

[0032] As already discussed above, the cold storage 4 can include a cold storage agent having a predetermined heat capacity to store a predetermined amount of cooling energy (e.g., an amount of cooling energy sufficient to fulfill the cooling energy requirements of the analysis system). The cold storage 4 can include an optional pumping device configured to circulate the cold storage agent in the cold storage. This can improve an efficiency of the deposition of cooling energy into the cold storage and the removal of cooling energy from the cold storage in some examples.

[0033] In one example, the cooling agent includes a liquid (in particular water). In one example, the cold storage agent can include a material that changes its aggregate state from a liquid aggregate state to a solid aggregate state when the main cooling circuit removes heat from the cold storage.

[0034] For instance, the cold storage 4 can include one or more ice banks. In the subsequent sections, an ice bank will be discussed as example cold storage 4. However, the centralized cooling devices of the present disclosure are not limited to ice banks. As discussed above, other cooling agents changing their aggregate states than water can be used in some examples. In other examples, the cooling agent does not change its aggregate state during the cooling process (but rather is cooled down by the main cooling circuit in a predetermined aggregate state). In still other examples, the cold storage stores cooling energy in a different form than by heat energy or latent energy (e.g., in the form of mechanical, electrical or magnetic energy).

[0035] After having clarified that a large variety of cold storages can be used in the systems of the present disclosure, the description of the example ice bank cold storage will now be resumed. As long as the ice bank includes a predetermined amount of ice, the cold storage has a temperature of at most approximately 0° Celsius and compartment cooling circuits 3a, 3b, 3c can deposit heat into this cold reservoir. In this manner, the ice buffers the cooling energy provided by the main cooling circuit 1. It is not required for the main cooling circuit to operate whenever the compartment cooling circuits 3a, 3b, 3c require cooling energy. Using an ice bank (with water as cold storage agent) can be advantageous as no potentially toxic or in other ways critical cold storage agents have to be used in the cold storage. This can render the cooling device and the regulatory approval process less complex and thus less costly particularly for analysis systems for biological samples.

[0036] The cold storage 4 can be thermally isolated. This can lengthen a period of time during which the cold storage 4 can buffer the cooling energy.

[0037] The compartment cooling circuits 3a, 3b, 3c will be considered in more detail subsequently. As can be seen in **Fig. 2**, all compartment cooling circuits 3a, 3b, 3c are coupled to the cold storage 4 jointly. The compartment cooling circuits 3a, 3b, 3c have a heat exchanger 9 configured to transfer heat from the compartment cooling circuits 3a, 3b, 3c to the cold storage agent of the cold storage 4. The compartment cooling circuits 3a, 3b, 3c can include a coolant. In one example, the compartment cooling circuits 3a, 3b, 3c include a liquid coolant (e.g., a liquid coolant including water).

[0038] In the example of **FIG. 2** the different compartment cooling circuits 3a, 3b, 3c are coupled and use a single heat exchanger 9. In other examples, two or more of the compartment cooling circuits 3a, 3b, 3c can be separate cooling circuits. In other words, the two or more compartment cooling circuits do not have to be in fluid communication (and optionally include their own heat exchangers for depositing heat into the cold storage, or being coupled to the same heat exchanger but not being in fluid communication).

[0039] In some examples, a compartment cooling circuit can be configured to be attachable and detachable from the analysis system. In this manner, additional compartments can easily be added to the analysis system. For example, an additional compartment cooling circuit can be coupled to the heat exchanger 9 of the of analysis system.

[0040] In the example of **FIG. 2**, each compartment cooling circuit 3a, 3b, 3c includes a temperature regulating unit for customizing the temperature of the respective compartment within a temperature range of e.g. +/- 5 degrees Celsius or less, e.g. +/- 2 degrees Celsius on the basis of the cooling energy provided by the cold storage. In particular, the cooling energy provided by the cold storage may be regulated in each compartment cooling circuit depending on the temperature requirements of the respective compartment, which may be different for different compartments and/or change over time for the same compartment. The temperature regulating unit may include a flow rate regulator 6a, 6b, 6c to regulate a flow of a coolant through the respective compartment cooling circuit 3a, 3b, 3c. In this manner, an amount of heat deposited into the cold storage 4 by the respective compartment cooling circuit 3a, 3b, 3c can be regulated. This can facilitate regulating a temperature inside the associated compartment 2a, 2b, 2c of the respective compartment cooling circuit 3a, 3b, 3c.

[0041] The flow rate regulators 6a, 6b, 6c can include one or more pumps to regulate an amount of coolant flowing through the respective compartment cooling circuit 3a, 3b, 3c. In addition or alternatively, the flow rate regulators 6a, 6b, 6c can include one or more controlled valves to regulate an amount of coolant flowing through the respective compartment cooling circuit 3a, 3b, 3c.

[0042] Even though in **FIG. 2** the flow rate regulators 6a, 6b, 6c are depicted as single elements between the cold storage 4 and the respective compartment 2a, 2b, 2c, this arrangement is purely illustrative. The flow rate regulator 6a, 6b, 6c can be embodied in a variety of different arrangements. For instance, the flow rate regulator 6a, 6b, 6c can be arranged at any suitable place of the respective compartment cooling circuit 3a, 3b, 3c and can include multiple separate components.

[0043] In the example of **FIG. 2**, each compartment cooling circuit 3a, 3b, 3c can include a dedicated flow rate regulator 6a, 6b, 6c. In other examples, one or more of the compartment cooling circuits can share a flow rate regulator with one or more other compartment cooling circuits. In addition or alternatively, two compartment cooling circuits can include different types of temperature regulating units with different functions. For instance, two or more (or all) compartment cooling circuits of an analysis system can share one or more pumping devices configured to move the coolant through each of the compartment cooling circuits. In addition or alternatively, two or more of the compartment cooling circuits can include a dedicated controlled valve to limit the flow of a coolant in the respective compartment cooling circuit. In the example of **Fig. 2**, the temperature regulating units include a heat exchanger 7a, 7b, 7c coupled to the respective compartment cooling circuit 3a, 3b, 3b. In addition, the temperature regulating units include optional fans 8a, 8b to facilitate cooling the respective compartment 2a, 2b (e.g., for moving colder air away from the heat exchangers 7a, 7b and warmer air towards the heat exchangers 7a, 7b). In particular, the fans 8a, 8b may have a controllable operational speed in order to increase or reduce the speed of heat transfer in each compartment.

[0044] The compartments 2a, 2b, 2c can include any compartment that requires cooling in an analysis system. For example, the analysis system can include one or more of a sample storage compartment, a reagent storage compartment, a reagent manipulator compartment, a sample manipulator compartment and a quality control compartment. In one example, one or more of the compartments 2a, 2b, 2c are adapted to handle or store sample tubes or reagents. The compartments can additionally include thermal isolation. In addition to the compartment cooling circuits described in the present disclosure, the compartments can also include optional further cooling devices (e.g., as back-up cooling devices or for handling short period cooling energy requirement peaks).

[0045] After different aspects of the components of a centralized cooling device for compartments of an analysis system have been discussed in the preceding sections, several details of modes of operation of the centralized cooling system will be discussed subsequently in connection with **FIG. 3** to **FIG. 6**. For the sake of illustration the example analysis system of **FIG. 3** to **FIG. 6** are drawn in a schematic manner. However, each of the systems depicted in **FIG. 3** to **FIG. 6** can include one or more of the components described above in connection with **FIG. 2**.

[0046] As depicted in **FIG. 3** the compartment cooling circuits 3a, 3b, 3c can operate independently from the main cooling circuit 1. For instance, the main cooling circuit 1 can be intermittently switched off. The compartment cooling circuits 3a, 3b, 3c can nevertheless deposit heat from the compartments into the cold storage 4. The compartment cooling circuits 3a, 3b, 3c utilize the cooling energy buffered in the cold storage 4.

[0047] In the same manner, as shown in **FIG. 4** the main cooling circuit can deposit cooling energy 4 into the cold storage independently of the operation of the compartment cooling circuits 3a, 3b, 3c. For instance, one or more of the compartment cooling circuits 3a, 3b, 3c can be disabled so that no or a reduced amount of heat is deposited in the cold storage 4 by the compartment cooling circuits 3a, 3b, 3c in certain periods of time. This can be the case, e.g., when the cooling system of the analysis system is being started or when additional compartment cooling circuits are being coupled to the cold storage 4.

[0048] In this manner, it can be possible to control the different cooling circuits independently. For instance, the main cooling circuit can include a controller which monitors an amount of cooling energy stored in the cold storage 4 and cools the cold storage 4 as soon as the amount of cooling energy falls within a predetermined level.

[0049] In one example, the amount of cooling energy can be determined by the controller in response to a temperature measurement of the cold storage agent inside the cold storage 4. The cold storage 4 can include one or more temperature sensors to measure a temperature of the cold storage agent inside the cold storage 4.

[0050] In addition or alternatively, the controller can determine an amount of cold storage agent in a particular aggregate state to monitor an amount of cooling energy stored in the cold storage 4. Moreover, the controller can drive the main cooling circuit to deposit additional cooling energy into the cold storage 4 in response to determining an amount of cold storage agent being in a particular aggregate state (e.g., in response to determining that an amount of cold storage agent in a solid state falls below a predetermined level or one of a plurality of predetermined levels).

[0051] In one example when the cold storage 4 includes one or more ice banks the controller can monitor an amount of ice present in the one or more ice banks and control the main cooling circuit in response to the amount of ice present. For instance, the controller can drive the main cooling circuit 1 to deposit cooling energy into the cold storage 4 when an amount of ice drops below a predetermined level (e.g., when no ice is left in the ice bank or when one of one or more reserve levels) of ice is reached.

[0052] In some examples, the controller might not have to monitor the amount of heat deposited into the cold storage 4 by the compartment cooling circuits 3a, 3b, 3c. The controller can be configured to secure that a certain amount of cooling energy is stored in the cold storage 4 (e.g., a minimum amount of ice in examples where the cold storage 4 includes an ice bank). This can ensure that the compartment cooling circuits 3a, 3b, 3c can deposit the required amount of heat into the cold storage 4 to cool the compartments 2a, 2b, 2c.

[0053] However, in other examples the controller can monitor an amount of heat deposited into the cold storage 4 by the compartment cooling circuits 3a, 3b, 3c. In addition or alternatively, the controller can estimate an amount of heat deposited into the cold storage 4 by the compartment cooling circuits 3a, 3b, 3c (in some examples without actually monitoring the compartment cooling circuits 3a, 3b, 3c.). The controller can then drive the main cooling circuit 1 to buffer a predetermined amount of cooling energy into the cold storage 4 based on the amount of heat deposited in the cold storage 4 by the compartment cooling circuits 3a, 3b, 3c. This can take place instead or in addition to controlling the main cooling circuit 1 in response to monitoring an amount of cooling energy stored in the cold storage 4 as described above.

[0054] In one example, the controller can monitor a temperature of the coolant, a flow volume of the coolant, or both in one or more flow or return lines (or in both the flow and return lines) of the compartment cooling circuits 3a, 3b, 3c to estimate an amount of energy deposited into the cold storage 4 by the respective compartment cooling circuits 3a, 3b, 3c. The compartment cooling circuits 3a, 3b, 3c can be equipped with one or more temperature sensors to measure the temperature of the coolant in the flow and return lines. A flow volume of the coolant in the flow and return lines of the compartment cooling circuits can be measured or estimated (e.g., based on the operation parameters of the flow control units).

[0055] In addition or alternatively, the controller can receive information regarding the temperature of the compartments to estimate an amount of energy deposited into the cold storage 4 (e.g., a future requirement of cooling energy of the respective compartment 2a, 2b, 2c). In still other examples, the controller can receive other information regarding a state of a compartment 2a, 2b, 2c (e.g., a door opening sensor of the compartment or a load state sensor of the compartment) to estimate an amount of energy deposited into the cold storage 4.

[0056] In one example, the controller can be configured to calculate an amount of cooling energy to be buffered based on statistical energy consumption information from the analysis system. For instance, the controller can calculate an amount of cooling energy to be buffered based on an average energy consumption of the attached compartments 2a, 2b, 2c over a predetermined period of time.

[0057] Additionally or alternatively, the controller can use information regarding a nominal energy consumption of the attached compartments 2a, 2b, 2c to calculate an amount of cooling energy to be buffered. For example, the controller can estimate an energy consumption for a particular type of compartment.

[0058] The controller can calculate a past and or future amount of deposited energy into the cold storage 4 based on one or more of the above discussed pieces of information and drive the main cooling circuit 1 in response to this calculation. In this manner, a sufficient amount of cooling energy can be buffered in the cold storage 4 to satisfy the cooling needs of the attached compartments 2a, 2b, 2c. In addition or alternatively, the controller can use one or more closed-loop or open-loop control schemes to determine a drive sequence of the main cooling circuit 1.

[0059] Controlling an amount of cooling energy stored into the cold storage based on the energy consumption of the compartment cooling circuits (e.g., by measuring the temperature and flow in the flow and return lines of the compartment cooling circuits) can provide for a simple and robust control parameter to control the main cooling system. In addition, the cooling device can be easily scalable to adapt for a variety of different numbers and sizes of compartments to be cooled in the analysis system.

[0060] After the controlling of the main cooling circuit has been explained in connection with **FIG. 3** and **FIG. 4**, different aspects of control methods of the compartment cooling circuits will be discussed subsequently in connection with **FIG. 5** and **FIG. 6**.

[0061] As can be seen in **FIG. 5**, the different compartments 2a, 2b, 2c can be individually cooled. For example, a first compartment 2a can be cooled to a first temperature while a second compartment 2b can be cooled to a second temperature. In other examples, a compartment cooling circuit of a particular compartment can be switched off while another compartment of the analysis system is cooled to a predetermined temperature. In addition or alternatively, one compartment 2a can be continuously cooled while another compartment 2c can be cooled intermittently (e.g., when a particular trigger event takes place).

[0062] The controller of the analysis system can effect the individual cooling of the compartments 2a, 2b, 2b by controlling temperature regulating units of the respective compartment cooling circuits 3a, 3b, 3c (e.g., flow regulators as discussed above in connection with **FIG. 2**), as discussed above in connection with **FIG. 2**).

[0063] In one example, the controller can change a flow of coolant through a particular compartment cooling circuit 3a, 3b, 3c to change an amount of heat extracted from the respective compartment 2a, 2b, 2c. For example, the controller can control a pump of a flow rate regulator of a compartment cooling circuit, a controlled valve of a flow rate regulator of a compartment cooling circuit, or both, to change a flow of coolant through the particular compartment cooling circuit 3a, 3b, 3c and thereby change an amount of heat extracted from the respective compartment 2a, 2b, 2c.

[0064] In addition or alternatively, the controller can change drive parameters of a fan of a temperature regulation unit (or a parameter of another controllable component of the temperature regulation unit) of a respective compartment 2a, 2b, 2c to change an amount of heat extracted from the respective compartment 2a, 2b, 2c.

[0065] In some examples, the controller receives information from one or more temperature sensors of the compartment 2a, 2b, 2c to estimate a temperature inside the particular compartments 2a, 2b, 2c and a required amount of heat that has to be extracted from the respective compartment 2a, 2b, 2c.

[0066] **FIG. 6** illustrates a further mode of operation of the controller of the compartment cooling circuits 3a, 3b, 3c. In some examples, the controller is configured to set priorities for the use of the buffered cooling energy by the different compartment cooling circuits 3a, 3b, 3c in case an insufficient amount of cooling energy is buffered.

[0067] For instance, the controller can reduce the amount of heat extracted from one or more compartments having a lower priority (e.g., by reducing or stopping a flow of coolant through the respective compartment cooling circuits) to secure that a higher priority compartment is adequately provided with cooling energy. In the example of **FIG. 6**, the compartment 2a is a prioritized compartment. For instance, the compartment 2a can contain biological samples or reagents very sensitive to storage temperatures while the compartments 2b, 2c can contain less sensitive reagents. The controller controls the compartment cooling circuits 3a, 3b, 3c to exclusively provide compartment 2a with cooling energy. In this manner, the cooling system of the present disclosure can provide for a fail safe state if, e.g., the main cooling circuit or the cold storage are temporarily or permanently unable to provide a sufficient cooling power to cool all compartments of the analysis system to their nominal temperatures.

[0068] Several additional optional aspects of the analysis systems of the present will be discussed subsequently.

[0069] Firstly, the analysis system can be optionally equipped with one or more devices to use waste heat generated in the main cooling circuit, the compartment cooling circuits, and/or the cold storage in the analysis system.

[0070] For instance, the analysis system can include a device configured to harvest a portion of heat generated in a condenser of the refrigeration device to generate energy or to heat one or more components of the analysis system. In one example, the analysis system further comprises one or more heaters and a heat transport circuit configured to transport the portion of the heat generated in the condenser to the one or more heaters.

[0071] Additionally or alternatively, the analysis system can transform waste heat generated in the main cooling circuit, the compartment cooling circuits, and/or the cold storage into electrical energy which can be used in the analysis system.

[0072] Additionally or alternatively, the analysis system can harvest at least a portion of latent heat liberated when a cold storage agent of the cold storage changes an aggregation state. Secondly, even though in the present disclosure different examples of cooling circuits are described, the described systems and methods can also be used to heat one or more compartments of an analysis system.

[0073] For example, an analysis system for analyzing biological samples can comprise a plurality of compartments, a plurality of compartment heating circuits, each of the plurality of compartment heating circuits is configured to heat at least one of the plurality of compartments, a main heating circuit separate from the one or more compartment heating circuits, the main heating circuit including a heat storage, the main heating circuit being coupled to the heat storage and configured to heat the heat storage, the one or more compartment heating circuits are coupled to the heat storage and the one or more compartment heating circuits being configured to transfer heat into the plurality of compartments from the heat storage to heat the plurality of compartments.

[0074] As can be seen, the heating system is fairly similar to the cooling system discussed above apart from that the direction of heat transfer is reversed. The different components of the cooling system described above and the different techniques to control a cooling system described above can equally be applied in a heating system (except for the components and techniques being specific to a cooling system).

[0075] In the preceding detailed description multiple examples of analysis systems of the present disclosure have been discussed. However, the analysis systems of the present disclosure can also be configured as set out in the following aspects:

1. An analysis system for analyzing biological samples, the analysis system comprising:

a plurality of compartments;
a plurality of compartment cooling circuits, wherein each of the plurality of compartment

cooling circuits is configured to cool at least one of the plurality of compartments;

a main cooling circuit separate from the one or more compartment cooling circuits, the main cooling circuit including a refrigeration device; and

a cold storage,

wherein the main cooling circuit is coupled to the cold storage and configured to cool the cold storage,

wherein the one or more compartment cooling circuits are coupled to the cold storage, and

wherein the one or more compartment cooling circuits are configured to transfer heat from the plurality of compartments into the cold storage to cool the plurality of compartments.

2. The analysis system of aspect 1 wherein the compartments include one or more of a sample storage compartment, a reagent storage compartment, a reagent manipulator compartment, a sample manipulator compartment and a quality control compartment.

3. The analysis system of aspect 1 or 2 wherein the refrigeration device is a cyclic refrigeration device.

4. The analysis system of aspect 3, wherein the cyclic refrigeration device includes a vapor cycle or a gas cycle.

5. The analysis system of aspect 3 or aspect 4 wherein the cyclic refrigeration device is a vapor-compression refrigeration device or a vapor-absorption refrigeration device.

6. The analysis system of any of aspects 3 to 5 wherein the cyclic refrigeration device includes at least one compressor, at least one expander and at least one condenser.

7. The analysis system of aspect 6 wherein a portion of heat generated in the condenser is used in the analysis system to generate energy or to heat one or more components of the analysis system.

8. The analysis system of aspect 7 wherein the analysis system further comprises one or more heaters and a heat transport circuit configured to transport the portion of the heat generated in the condenser to the one or more heaters.

9. The analysis system of any of the preceding aspects, wherein any one or more of the compartment cooling circuits includes a temperature regulating unit for adjusting the temperature of the respective compartment.

10. The analysis system of aspect 9 wherein the temperature regulating unit includes a flow rate regulator.

11. The analysis system of aspect 10 wherein the flow regulator element includes a pump configured to pump a cooling agent through the respective compartment cooling circuit.

12. The analysis system of one of the preceding aspects wherein two or more compartment cooling circuits are in fluid communication.

13. The analysis system of any one of the preceding aspects wherein the two or more cooling circuits share a pump configured to pump a cooling agent through the respective compartment cooling circuit.

14. The analysis system of any of the aspects 10 to 13 wherein the flow rate regulator includes a controlled valve.

15. The analysis system of one of the aspects 9 to 14 wherein the temperature regulating unit includes a heat exchanger configured to transfer heat from the respective compartment to the respective compartment cooling circuit.

16. The analysis system of aspect 15 wherein the temperature regulating unit includes a fan configured to effect heat transport towards the respective heat exchanger.

17. The analysis system of one of the preceding aspects wherein the cold storage includes a cold storage agent which is configured to change its aggregate state when the main cooling circuit cools the cold storage.

18. The analysis system of aspect 17 wherein the cold storage agent which is configured to change its aggregate state from a fluid state to a solid state when the main cooling circuit cools the cold storage.

19. The analysis system of any one of aspects 17 or 18 wherein the cold storage includes a pumping device configured to circulate the cold storage agent in the cold storage.

20. The analysis system of one of the preceding aspects wherein the cold storage includes one or more ice banks.

21. The analysis system of any one of the preceding aspects wherein the main cooling circuit is configured to operate intermittently to cool the cold storage.

22. The analysis system of one of the preceding as-

pects wherein the main cooling circuit includes multiple refrigeration cycles.

23. The analysis system of any one of the preceding aspects wherein the cold storage is adapted to buffer cooling energy.

24. The analysis system of aspect 23 further comprising a controller configured to monitor an amount of energy buffered in the cold storage and control the main cooling circuit in response to the measured amount of energy in the cold storage.

25. The analysis system of aspect 24 wherein the cold storage includes one or more ice banks and the controller monitors an amount of ice present in the one or more ice banks.

26. The analysis system of aspect 25 wherein the controller is configured to detect if an amount of ice present in the one or more ice banks fall below a predetermined threshold and wherein the controller is configured to control the main cooling circuit to increase an amount of ice present in the one or more ice banks in response to detecting that the amount of ice present in the one or more ice banks fall below the predetermined threshold.

27. The analysis system of any one of aspects 24 to 26 wherein the controller is further configured to monitor temperatures in one or more flow or return lines of the plurality of compartment cooling circuits and control the main cooling circuit in response to the measured temperature in the one or more flow or return lines of the plurality of compartment cooling circuits.

28. The analysis system of aspect 27 wherein controlling the main cooling circuit in response to the measured temperatures includes estimating an amount of heat energy deposited in the cold storage by the plurality of compartments cooling circuits.

29. The analysis system of any of the aspects 23 to 27 wherein the controller is configured to calculate an amount of cooling energy to be buffered based on statistical energy consumption information from the analysis system.

30. The analysis system of any of the aspects 23 to 29 wherein the controller is configured to control the temperature regulating unit(s) in order to individually adjust the temperatures of individual compartments according to the respective compartment requirements.

31. The analysis system of any of the aspects 23 to 30 wherein the controller is configured to set priorities for the use of the buffered cooling energy by the different compartment cooling circuits in case an insufficient amount of cooling energy is buffered.

32. The analysis system of any one of the preceding aspects wherein each of the plurality of compartment cooling circuits is detachably connected to the analysis system.

33. A method for cooling a plurality of compartments of an analysis system analyzing biological samples, the method comprising:

cooling a cold storage by a main cooling circuit including a refrigeration device;
depositing heat into the cold storage by a plurality of compartment cooling circuits to cool the plurality of compartments of the analysis system, the plurality of compartments cooling circuits being separate from the main cooling circuit.

34. The method of aspect 33 wherein cooling the cold storage includes changing the aggregate state of a cold storage agent from a fluid state to a solid state in order to buffer an amount of cooling energy.

35. The method of aspect 33 or 34, further comprising:

controlling an amount of heat extracted from the cold storage in response to one or more of a temperature of the cold storage, an amount of a cold storage agent being in a predetermined aggregate state and an amount of heat deposited in the cold storage by the plurality of compartments cooling circuits.

36. The method of any one of the aspects 33 to 35 further comprising measuring temperatures in one or more flow or return lines of the plurality of compartment cooling circuits to determine an amount of heat deposited in the cold storage by the plurality of compartments cooling circuits.

37. The method of aspect 36 further comprising controlling a cooling power of the main cooling circuit in response to the measured temperatures.

38. The method of any one of the aspects 33 to 37 further comprising calculating an amount of cooling energy to be buffered based on statistical energy consumption information from the analysis system.

39. The method of any one of the aspects 33 to 38 further comprising controlling the temperature regulating unit(s) in order to individually adjust the temperatures of individual compartments according to

the respective compartment requirements.

40. The method of aspect 39 wherein individually adjusting the temperatures comprises changing the flow rate in any of the individual compartment cooling circuits and/or compartment fan speed.

41. The method of any one of the aspects 33 to 40 comprising setting priorities for the use of the buffered cooling energy by the different compartment cooling circuits in case an insufficient amount of cooling energy is buffered.

Claims

1. An analysis system for analyzing biological samples, the analysis system comprising:

   a plurality of compartments (2a; 2b; 2c);
   a plurality of compartment cooling circuits (3a; 3b; 3c),
   wherein each of the plurality of compartment cooling circuits (3a; 3b; 3c) is configured to cool at least one of the plurality of compartments (2a; 2b; 2c);
   a main cooling circuit (1) separate from the one or more compartment cooling circuits (3a; 3b; 3c), the main cooling circuit (1) including a refrigeration device (10-13); and
   a cold storage (4),
   wherein the main cooling circuit (1) is coupled to the cold storage (4) and configured to cool the cold storage (4),
   wherein the one or more compartment cooling circuits (3a; 3b; 3c) are coupled to the cold storage (4), and
   wherein the one or more compartment cooling circuits (3a; 3b; 3c) are configured to transfer heat from the plurality of compartments (2a; 2b; 2c) into the cold storage (4) to cool the plurality of compartments (2a; 2b; 2c).

2. The analysis system of claim 1 wherein the compartments (2a; 2b; 2c) include one or more of a sample storage compartment, a reagent storage compartment, a reagent manipulator compartment, a sample manipulator compartment and a quality control compartment.

3. The analysis system of claim 1 or 2 wherein the refrigeration device (10-13) is a cyclic refrigeration device, preferably wherein the cyclic refrigeration device (10-13) is a vapor-compression refrigeration device or a vapor-absorption refrigeration device.

4. The analysis system of claim 3 wherein the cyclic refrigeration device (10-13) includes at least one compressor (11), at least one expander (12) and at least one condenser (10), wherein a portion of heat generated in the condenser (10) is used in the analysis system to generate energy or to heat one or more components of the analysis system.

5. The analysis system of any of the preceding claims, wherein any one or more of the compartment cooling circuits (3a; 3b; 3c) includes a temperature regulating unit (6a; 6b; 6c; 7a; 7b; 7c) for adjusting the temperature of the respective compartment (2a; 2b; 2c).

6. The analysis system of claim 5 wherein the temperature regulating unit includes a flow rate regulator (6a; 6b; 6c).

7. The analysis system of claim 6 wherein the flow rate regulator (6a; 6b; 6c) includes a controlled valve.

8. The analysis system of one of the preceding claims wherein the cold storage includes (4) one or more ice banks.

9. The analysis system of any one of the preceding claims wherein the main cooling circuit (1) is configured to operate intermittently to cool the cold storage (4).

10. The analysis system of any one of the preceding claims wherein the cold storage (4) is adapted to buffer cooling energy.

11. The analysis system of claim 10 further comprising a controller configured to monitor an amount of energy buffered in the cold storage (4) and control the main cooling circuit (1) in response to the measured amount of energy in the cold storage (4).

12. The analysis system of claim 11 wherein the controller is configured to calculate an amount of cooling energy to be buffered based on statistical energy consumption information from the analysis system.

13. The analysis system of any of the claims 11 to 12 wherein the controller is configured to control the temperature regulating unit(s) (6a; 6b; 6c; 7a; 7b; 7c) in order to individually adjust the temperatures of individual compartments (2a; 2b; 2c) according to requirements of the respective compartment (2a; 2b; 2c).

14. The analysis system of any of the claims 11 to 13 wherein the controller is configured to set priorities for the use of the buffered cooling energy by the different compartment cooling circuits (3a; 3b; 3c) in case an insufficient amount of cooling energy is buffered.

15. A method for cooling a plurality of compartments (2a; 2b; 2c) of an analysis system analyzing biological samples, the method comprising:

cooling a cold storage (4) by a main cooling circuit (1) including a refrigeration device (10-13); depositing heat into the cold storage (4) by a plurality of compartment cooling circuits (3a; 3b; 3) to cool the plurality of compartments (2a; 2b; 2c) of the analysis system,
the plurality of compartments cooling circuits (3a; 3b; 3c) being separate from the main cooling circuit (1).

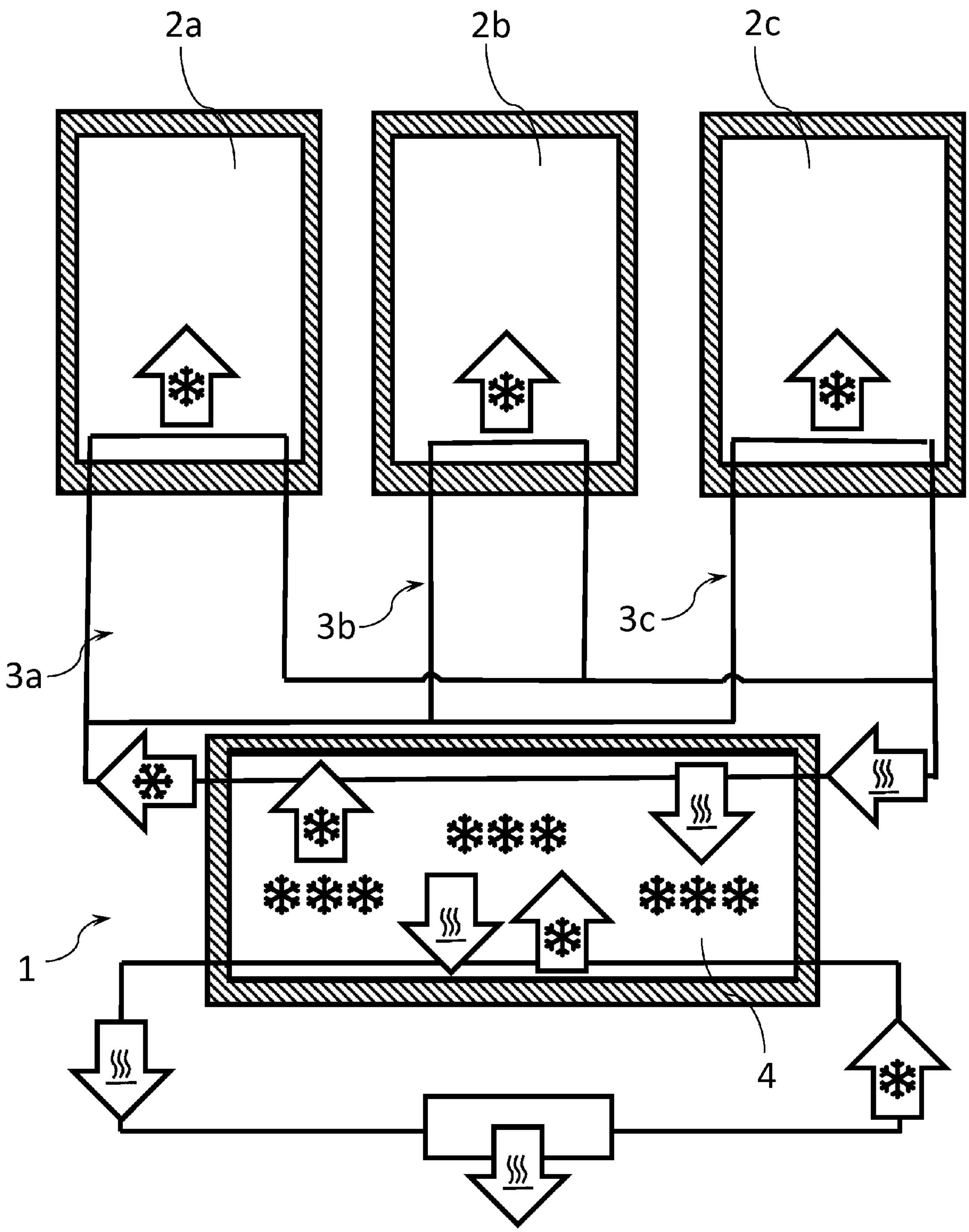

Figure 1

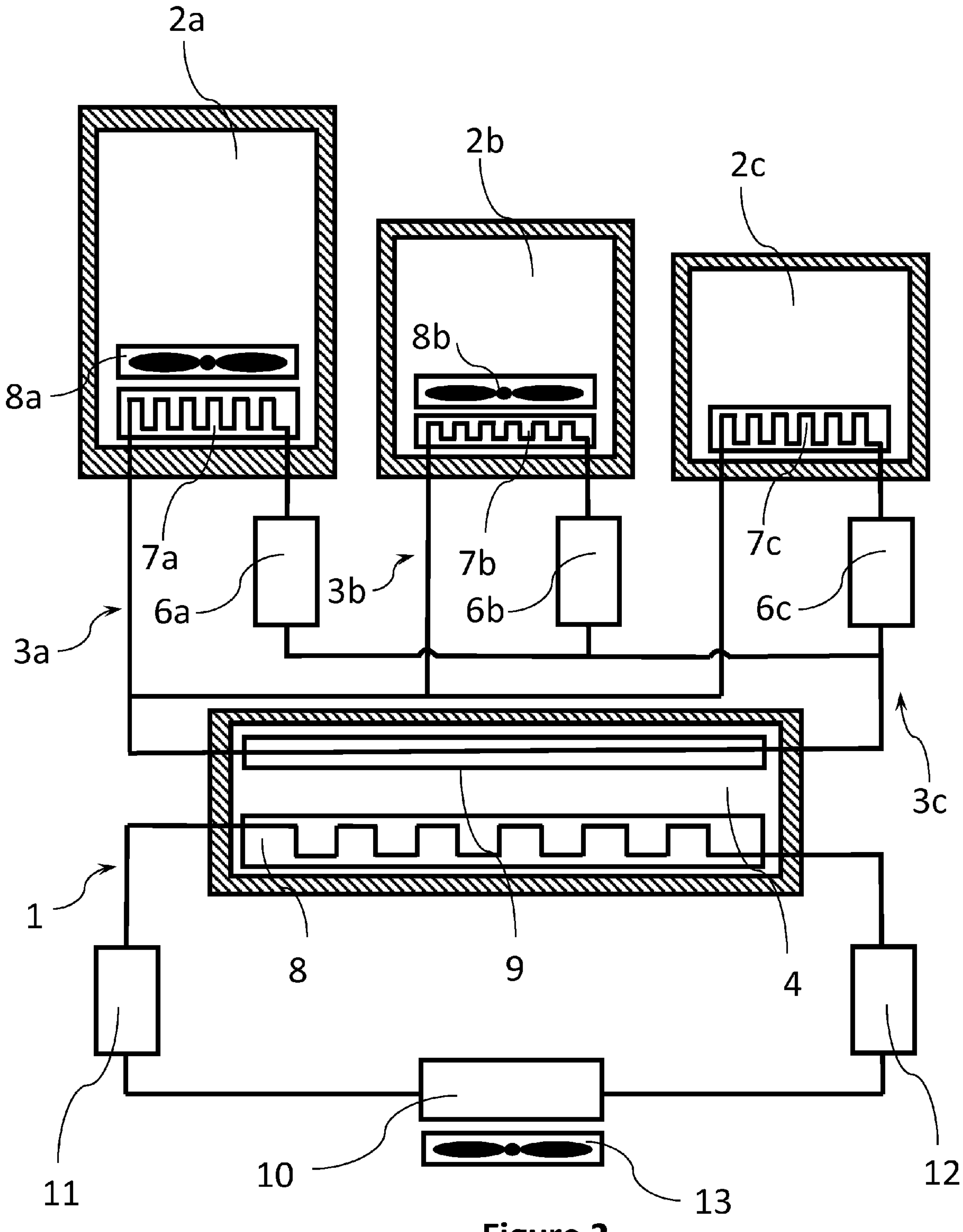

Figure 2

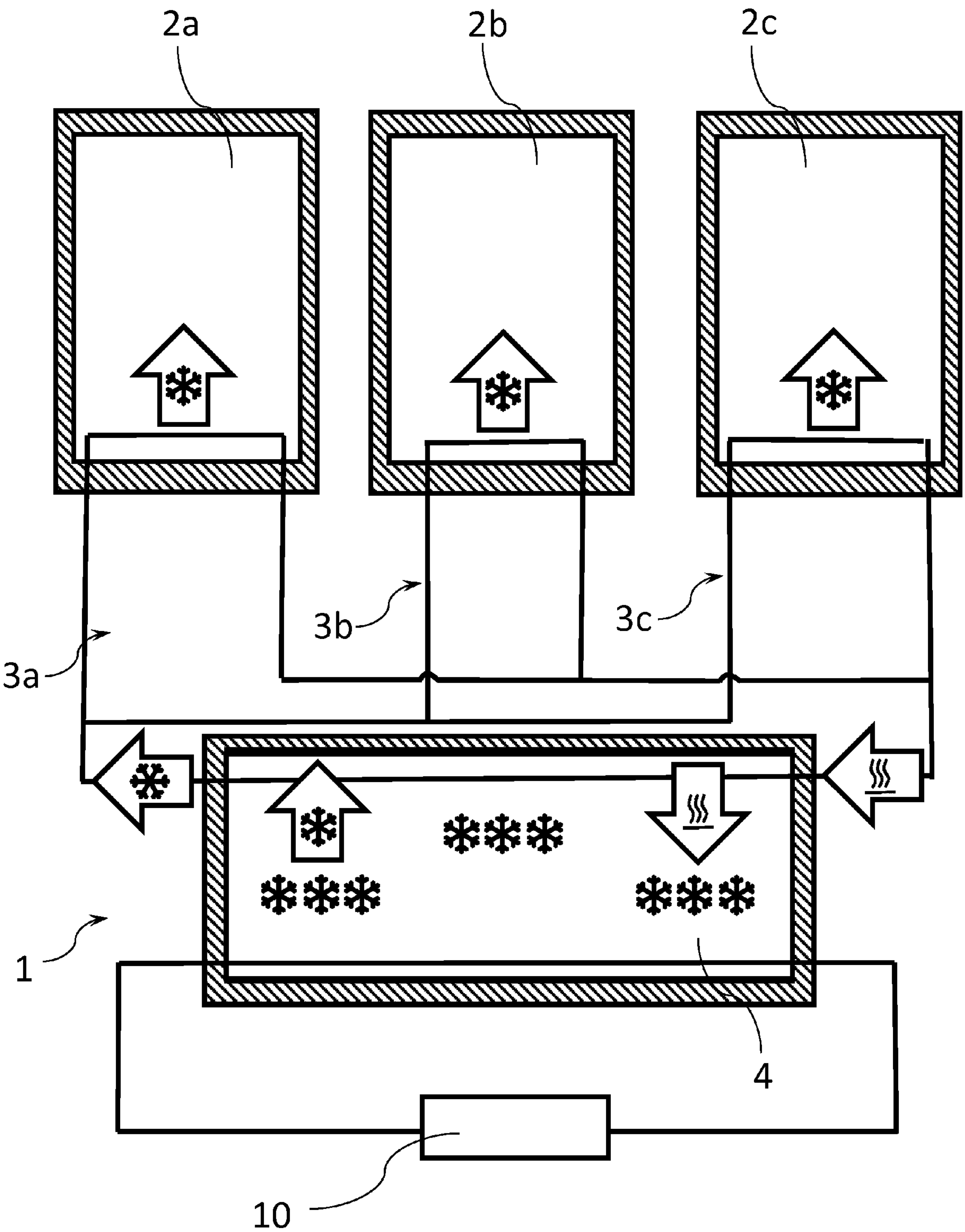

Figure 3

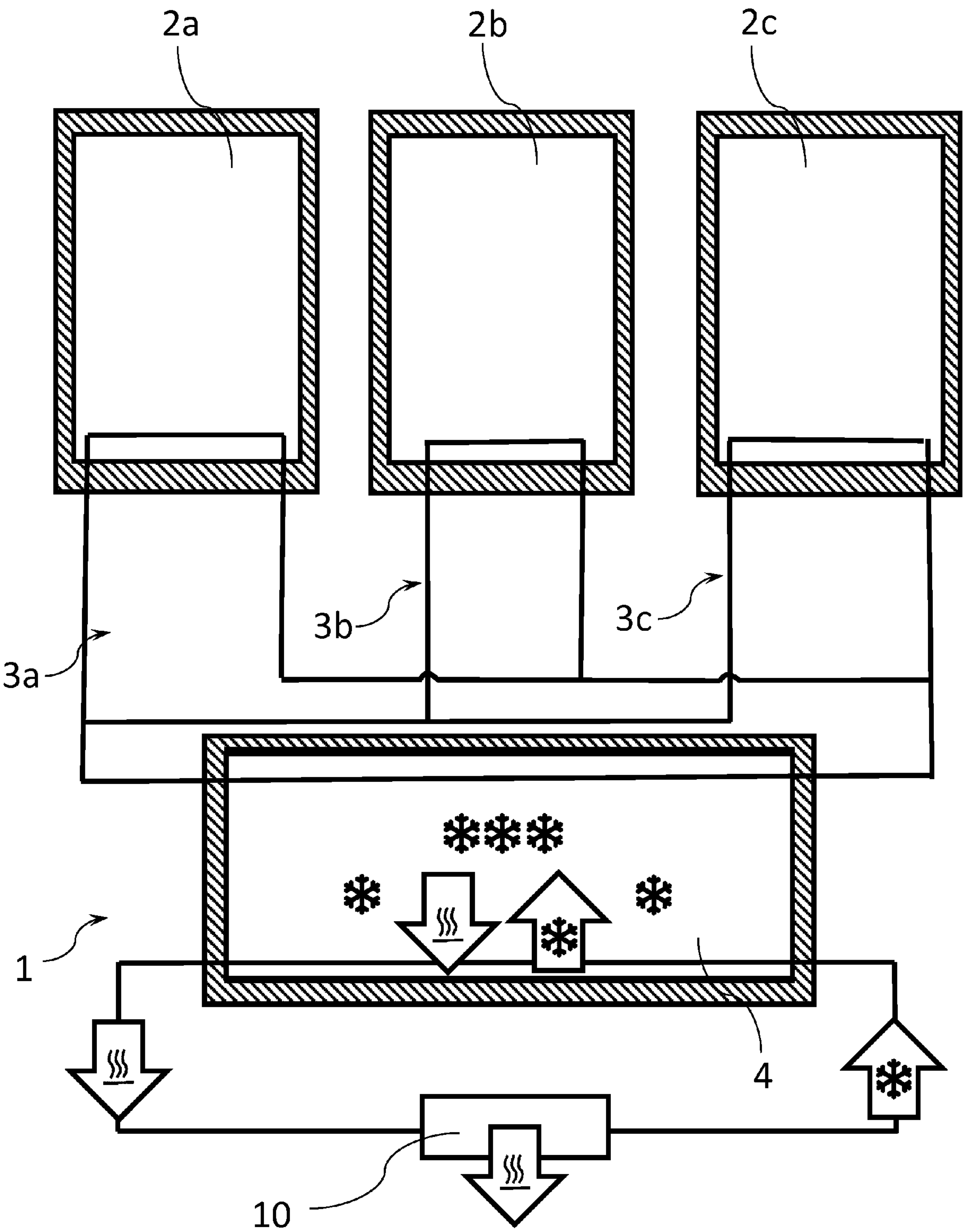

Figure 4

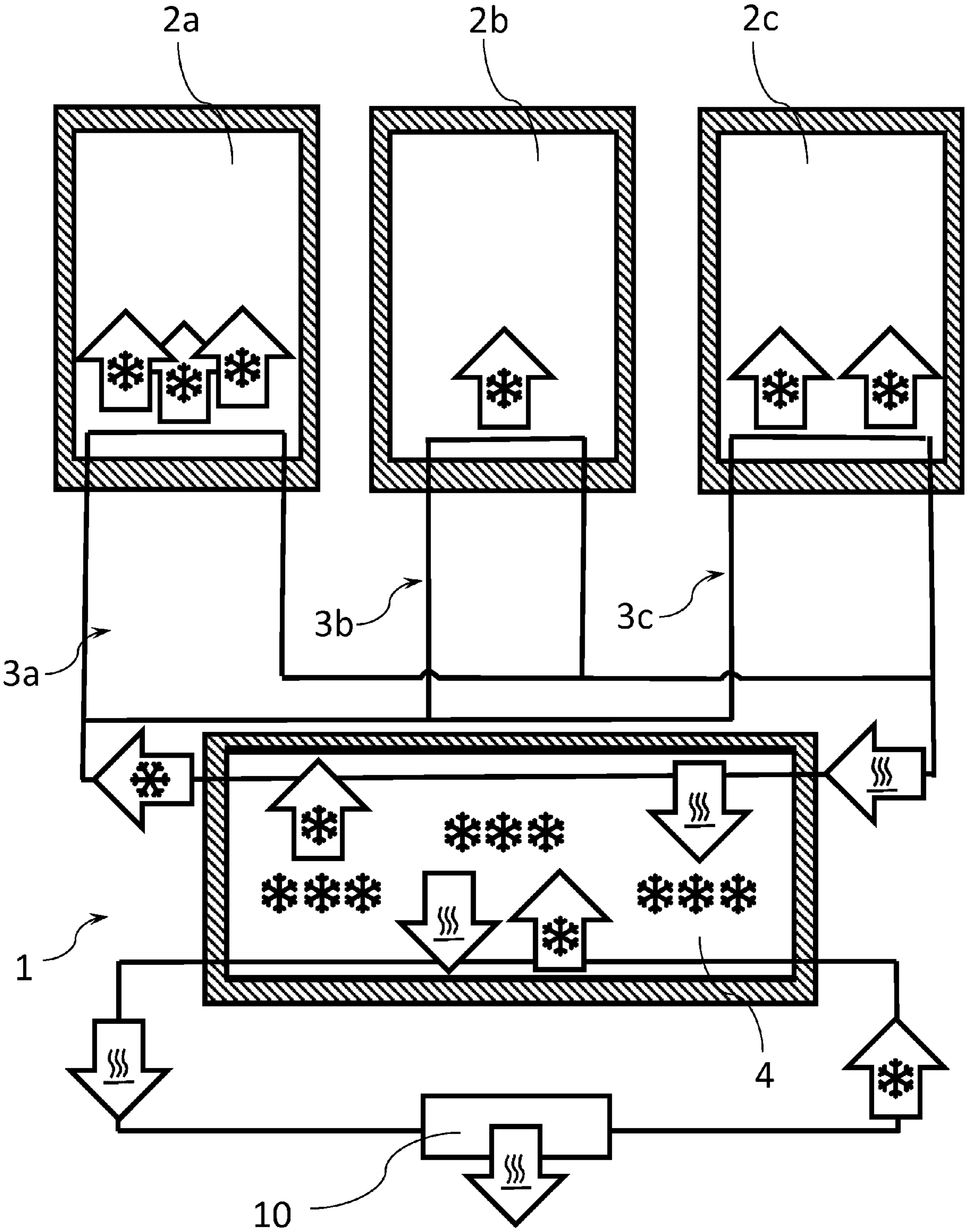

Figure 5

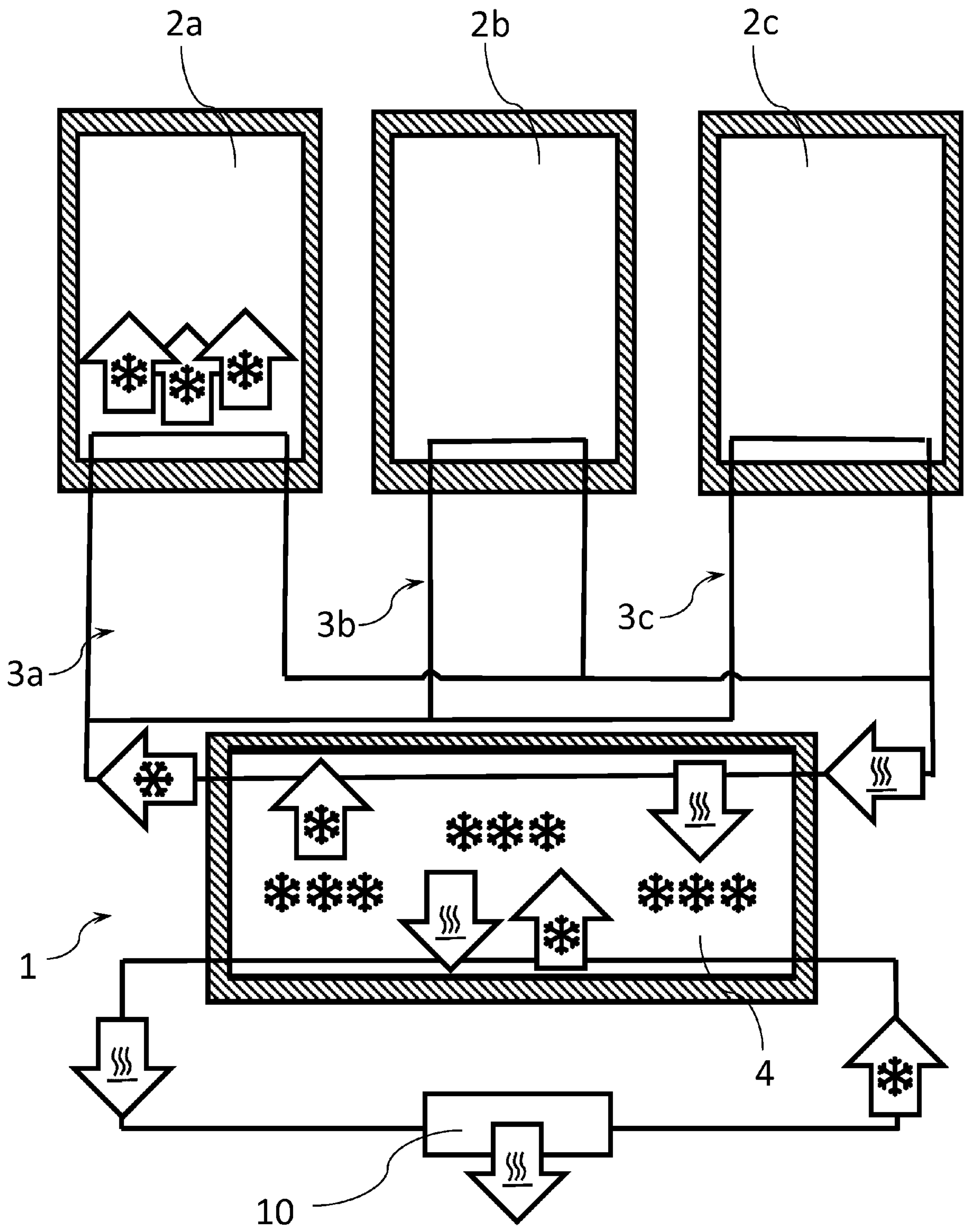

Figure 6

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EUROPEAN SEARCH REPORT

Application Number
EP 15 18 6701

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	24 February 2016	de Graaf, Jan Douwe

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EUROPEAN SEARCH REPORT

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