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(54) **Method and apparatus for defrosting a refrigeration apparatus**

(57) During a defrost process of a refrigeration apparatus (200), a flow rate of air is detected through an item (222) that is susceptible to frosting. The defrost process is stopped in response to the detected air flow rate being greater than a threshold flow rate.

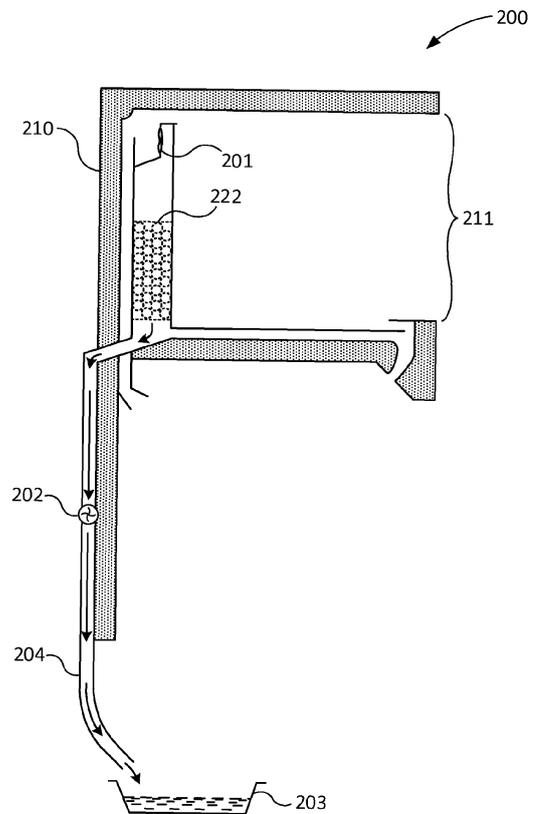


Figure 2

Description

Technical Field

[0001] The present disclosure relates to methods and apparatus for defrosting a refrigeration apparatus.

Background

[0002] So-called frost-free refrigeration apparatus, such as freezers and refrigerators and the like, employ various complex methods for preventing a build-up of ice. One example of such a method is periodically heating the freezer or refrigerator to melt any ice that may have formed inside. This process can be wasteful and inefficient.

Summary

[0003] According to a first aspect disclosed herein, there is provided a method of controlling of defrosting of a refrigeration apparatus, the method comprising: during a defrost process, detecting a flow rate of air through an item that is susceptible to frosting; and stopping the defrost process in response to the detected air flow rate being greater than a threshold flow rate.

[0004] In an example, the method comprises initiating the defrost process in response to a detected air flow rate through the item being less than a second threshold flow rate.

[0005] In an example, the method comprises detecting a fill level of a vaporisation tank storing liquid water resulting from the defrost process, and the defrost process is stopped in response to the detected fill level reaching a predetermined threshold fill level.

[0006] In an example, the method comprises initiating the defrost process in response to a detected air flow rate through the item being less than a second threshold flow rate, detecting a fill level of a vaporisation tank storing liquid water resulting from the defrost process and stopping the defrost process in response to the detected fill level reaching a predetermined threshold fill level, and the second threshold flow rate is lowered in response to the detected fill level reaching the predetermined threshold fill level.

[0007] In an example, the fill level of the vaporisation tank is determined based on measuring a flow rate during the defrost process.

[0008] In an example, the fill level of the vaporisation tank is determined based on receiving data from a fill level sensor of the vaporisation tank.

[0009] In an example, the second threshold is equal to the first threshold.

[0010] In an example, measuring the air flow rate comprises activating a fan arranged to blow air through the item.

[0011] In an example, the air flow rate is measured periodically.

[0012] According to a second aspect disclosed herein, there is provided a refrigeration apparatus comprising: a flow rate sensor for detecting a flow rate of air through an item that is susceptible to frosting; the refrigeration apparatus being configured to: stop a defrost process being carried out by the refrigeration apparatus in response to the detected air flow rate being greater than a threshold flow rate.

[0013] In an example, the refrigeration apparatus is configured to initiate a defrost process in response to a detected air flow rate through the item being less than a second threshold flow rate.

[0014] In an example, the refrigeration apparatus comprises a fan for blowing air through the item that is susceptible to frosting.

[0015] In an example, the refrigeration apparatus is configured to stop the defrost process in response to the detected fill level reaching a predetermined threshold fill level.

[0016] In an example, the refrigeration apparatus is configured to determine the fill level of the vaporisation tank based on measuring a flow rate during the defrost process.

[0017] In an example, the refrigeration apparatus comprises a fill level sensor for detecting the fill level of a vaporisation tank.

Brief Description of the Drawings

[0018] To assist understanding of the present disclosure and to show how embodiments may be put into effect, reference is made by way of example to the accompanying drawings in which:

Figure 1 shows schematically a refrigeration apparatus implementing a refrigeration cycle for cooling a space;

Figure 2 shows schematically a refrigeration apparatus in accordance with examples described herein; and

Figure 3 shows schematically an example control system for controlling the refrigeration apparatus.

Detailed Description

[0019] As mentioned previously, refrigeration apparatus, such as for example frost-free freezers and refrigerators and the like, prevent a build-up of ice, using relatively complex or inefficient methods. One such method is periodically restricting a cooling system or heating parts of the refrigeration apparatus to allow or cause any ice that may have formed to melt. Such methods have no regard for how much ice has actually formed.

[0020] According to examples disclosed herein, an air flow rate on a downstream side of an item, such as for example an evaporator, can be used to control a defrost

process. Specifically, a defrost process is stopped in response to a detected air flow rate rising above a threshold level. The defrost process may be initiated in response to a detected flow rate dropping below a (potentially different) threshold level. The ice on an item which is susceptible to frosting, such as an evaporator or other component of the refrigeration apparatus, will slowly build over time. If the item is placed in the path of an air flow, then the air flow will encounter increased resistance as the ice builds up. This means that the "output" flow rate of air (on the downstream side of the item) decreases with increasing frost on the item.

[0021] Figure 1 shows schematically an example of a known refrigeration apparatus 100 for implementing a vapour-compression refrigeration cycle to cool a space 110. Specifically, in this example the vapour-compression refrigeration cycle (described in more detail below) is implemented to cool a freezer portion 111 of the space 110 to below 0°C. Other portions of the space 110 will be cooled too depending on the temperature of the freezer portion 111 and the layout of the refrigeration apparatus 100. In any case, the freezer portion 111 represents a subsection of the space 110 in which substances such as foodstuffs may be placed to freeze them. More generally, the vapour-compression refrigeration cycle may be used to cool a space 110 of a refrigeration apparatus 100 even if the refrigeration apparatus 100 does not have a freezer portion as such.

[0022] The refrigeration apparatus 100 comprises a closed circuit of tubing 120 containing a selected refrigerant for cooling the interior of a space 110 (e.g. a food-stuff-storing portion of a refrigeration apparatus). Specifically, the circuit of tubing 120 includes an internal section 122 located within the freezer portion 111 and an external section 124 located outside the space 110.

[0023] The refrigerant is selected having a temperature of vaporisation such that it will vaporise in the internal section 122 as it absorbs heat from the interior of the freezer portion 111. For this reason, the internal section 122 may also be referred to as an evaporator 122.

[0024] A compressor 123 is provided to compress the vaporised refrigerant and so raise its temperature significantly. The high pressure, high temperature refrigerant vapour passes from the compressor 123 through the "hot" external section 124 of the circuit 120. The external section 124 acts as a condenser in the refrigeration cycle, transferring heat to the environment (e.g. the room in which the refrigeration apparatus 100 is located). A heat-sink or fan may be provided to improve the transfer of heat. The transfer of heat causes at least some of the refrigerant vapour in the external section 124 to condense back to a liquid form.

[0025] The high pressure refrigerant, now cooled and at least partially in liquid form, passes to an expansion valve 121 which reduces the pressure of the refrigerant, causing it to expand and cool. The low pressure low temperature refrigerant then passes through the evaporator 122 within the freezer portion 111, acting as an evapo-

rator in the refrigeration cycle, to absorb heat from the interior of the freezer portion 111. As a result, the cool refrigerant liquid passing through the evaporator 122 vaporises before passing on to the compressor 123 to complete the refrigeration cycle.

[0026] The compressor 123 may be driven by a low power DC motor, selected according to the refrigerant vapour pressure and temperature required in the external section 124 of the circuit and the rate of cooling required by the evaporator 122 of the circuit.

[0027] Because of the low temperatures generated within the freezer portion 111 by the evaporator 122 of the tubing 120, humidity from the air may freeze to the evaporator 122, causing an ice layer to build up over time. The ice build-up (also called "frost") on the evaporator 122 and/or in other parts of the refrigeration apparatus 100 is undesirable because it occupies space within the freezer portion 111 or other parts of the refrigeration apparatus 100, which could otherwise be used for storage (e.g. of foodstuffs) and reduces the efficiency of the refrigeration apparatus 100. A user of the refrigeration apparatus may "defrost" the refrigeration apparatus 100 periodically by allowing the freezer portion 111 to heat up to a point at which the ice melts, and then removing the resulting liquid water. Some known refrigeration apparatus have a mechanism, such as a heating resistor or other heating element, for heating up the freezer portion 111 briefly in order to melt the ice layer and thereby defrost the freezer portion 111. Such a "defrost process" may be performed automatically and periodically on a cycle, irrespective of how much frost has actually built up on the evaporator 122.

[0028] Figure 2 shows schematically a refrigeration apparatus 200 in accordance with examples described herein. The refrigeration apparatus 200 has a space 210 in which a freezer portion 211 is cooled by an evaporator 222 so as to be below 0°C, in the same manner described above in relation to the space 110, freezer portion 111 and evaporator 122 of Figure 1. The principles discussed herein may also be applied to a refrigeration apparatus 200 that does not have a freezer portion as such and the interior of which is (only) cooled to temperatures above freezing.

[0029] The refrigeration apparatus 200 comprises a fan 201 which is arranged to blow air through the evaporator 222. This arrangement is such that the air flow will be increasingly blocked as frost builds up on the evaporator 222. The fan 201 is, in the example of Figure 2, located above the evaporator 222. In this arrangement, the fan 201 is configured to blow air downwards through the evaporator 222. The fan 201 is therefore located on an "upstream" side of the evaporator 222 and air leaves the evaporator 222 (when not completely blocked by frost build-up) on the "downstream" side of the evaporator 222.

[0030] Melted frost will drip from the evaporator 222 in the form of liquid water on the downstream side. A pipe 204 is provided for directing this liquid water into a va-

porisation tank 203. Water in the vaporisation tank 204 will slowly evaporate into the environment. In some examples, the vaporisation tank 204 may be removable such that a user can manually empty the vaporisation tank 204.

[0031] The refrigeration apparatus 200 also comprises a flow sensor 202 for measuring a flow rate through the pipe 204. That is, the flow sensor 202 is located on the downstream side of the evaporator 222 for measuring air flow through the pipe 204. As mentioned above, the flow rate changes depending on the amount of ice build-up on the evaporator 222 and therefore can be used to control the timing of a defrost process. An example of a suitable type of flow sensor is a paddle wheel, though other types of flow sensor may be used. (In one specific example, the flow sensor 202 may also measure a water flow rate through the pipe 204, as will be discussed further below.)

[0032] Measurements of the air flow rate during normal operation (not during a defrost process) can be used to determine when too much frost has built up on the evaporator, and so a defrost process should be started. This may be performed in response to the air flow rate dropping below a threshold value.

[0033] Measurements of the flow rate during a defrost process (whilst the frost is being melted) can be used to determine when enough frost has been melted, and so the defrost process should be ended. This may be performed in response to the flow rate returning to a baseline level (e.g. if all the frost is to be melted), or other threshold value, depending on how much frost is intended to be melted.

[0034] Figure 3 shows schematically a control system for controlling the refrigeration apparatus 200 described above in relation to Figure 2. The control system comprises at least a controller 300, which may be a processor or the like, the flow rate sensor 202 and fan 201 described above, and a heating resistor 302 or other defrost mechanism as mentioned above in relation to Figure 1. In some examples, the control system also comprises a fill level sensor 301 for measuring a fill level of the vaporisation tank 204. The controller 300 is operably coupled to each of the flow rate sensor 202, fill level sensor 301, the fan 201, and the resistor 301 (or other defrost mechanism).

[0035] During normal operation of the refrigeration apparatus 200, the controller 300 is configured to activate the fan 201 to blow air through the evaporator 222 as described above, and simultaneously receive flow rate data from flow rate sensor 202 indicative of a flow rate through the pipe 204. This may be carried out periodically, of the order of for example every few hours, such as once a day or every 6 hours or so. When there is no frost present on the evaporator 222, the measured flow rate will be at a maximum. The controller 300 may be preconfigured with the value of this maximum (or "baseline") flow rate stored in an internal data storage (not shown in Figure 3). In another example, the controller 3000 may be configured to perform a commissioning step in which

the baseline flow rate is measured, e.g. upon installation, and stored to the internal data storage.

[0036] A start threshold flow rate value at which a defrost process is triggered may be stored in an internal data storage accessible by the controller 300. The controller 300 is configured to compare the measured flow rate with the start threshold flow rate, and to trigger a defrost process in response to the detected flow rate being less than the start threshold flow rate.

[0037] Triggering the defrost process may comprise controlling the resistor 302 to heat up the evaporator 222 sufficiently to cause the frost to begin to melt. Other mechanisms for enacting a defrost process are possible.

[0038] During the defrost process, the controller 300 periodically turns on the fan 201 and measure the flow rate at the flow rate sensor 301. This may be carried out relatively frequently, of the order of for example every few minutes, such as every 5 minutes or so. An end threshold flow rate value at which a defrost process is ended may be stored in an internal storage device accessible by the controller 300. The controller 300 is configured to compare the measured flow rate with the end threshold flow rate, and to stop the defrost process in response to the detected flow rate being greater than the end threshold flow rate.

[0039] The end threshold flow rate and start threshold flow rate may be (substantially) equal. In such cases, the defrost process is begun when the flow rate drops below the threshold and is stopped when the flow rate returns to above the (same) threshold. There may nevertheless be a small difference between the start and end threshold air flow rates to prevent the defrost process repeatedly starting and stopping.

[0040] During the defrost process, while the fan 201 is turned off, all flow measured by the flow rate sensor 202 is indicative of liquid water resulting from the melting of the frost. The controller 300 may be configured to determine, from this flow data, a volume of water which has been defrosted so far. Hence, the controller 300 is able to determine a fill level of the vaporisation tank 203 based on liquid flow rate. Alternatively or additionally, a fill level sensor 301 may be provided at the vaporisation tank 301 in order to directly determine the fill level of the vaporisation tank 203. In any case, the controller 300 may store (e.g. on the internal data storage) a maximum capacity of the vaporisation tank 203. Therefore, the controller 300 is able to determine how full the vaporisation tank is, and in particular when the vaporisation tank 203 is full.

[0041] However the fill level of the vaporisation tank 203 is determined, the controller 300 may be configured to stop the defrost process in response to the determined fill level reaching a threshold fill level. That is, in an example the controller 300 is configured with two conditions for stopping the defrost process: a first condition being that, when the fan is operated to blow air during the defrost process, the detected air flow rate exceeds the end threshold; and a second condition being that the determined fill level of the vaporisation tank 203 exceeds the

threshold fill level. The controller 300 is configured to stop the defrost process upon either condition being met (i.e. whichever condition is met first).

[0042] The controller 300 may lower the start threshold in response to determining that the vaporisation tank 203 is full. This means that the (current) defrost process will stop, as the threshold is not yet met. It also means that more frost will have to form on the evaporator 222 (reducing the flow rate) before the next defrost process is triggered. This gives time for water in the vaporisation tank 203 to evaporate, creating space for more water.

[0043] The above is just one example. That is, the controller 300 may lower the start threshold based on the current fill level of the vaporisation tank 203, not just when the vaporisation tank 203 is full.

[0044] To illustrate this more explicitly, in a specific example, the initial air flow rate may be $0.2\text{m}^3/\text{min}$ and controller 300 measures air flow every 6 hours. When the controller 300 determines that the air flow rate reduces to $0.1\text{m}^3/\text{min}$ (the threshold), it starts a defrost process (e.g. using resistor 302).

[0045] During the defrost process itself, the water flow rate may be 80 cl/min (liquid water resulting from the defrosting of ice). This will be the value measured by the flow rate sensor 202 when the fan 201 is not active. Note that this is typically much less than the air flow rate generated by the fan 201.

[0046] Periodically, e.g. every few minutes, such as every 5 or 10 minutes or so, the fan 201 is turned on for e.g. a few seconds, such as 5 seconds or so, and the controller 300 determines the air flow rate using the flow rate sensor 202. Note that this time the measured flow rate will be contributed to by both the air and the water. However, the fan 201 can be configured to generate a sufficiently high air flow rate that the water flow rate (which will be small due to resulting from a slow melting process) will be negligible compared to the air flow rate. Hence, it can be assumed that the measured flow rate during this time is substantially due to air alone. The initial air flow rate ($0.2\text{m}^3/\text{min}$ in this example) may be set as a "target" flow rate at which the defrost process is to be ended.

[0047] Consider an example in which, whilst attempting to reach the target flow rate, e.g. after 20 min of defrosting, 1.6L water reaches the vaporisation tank 203 (e.g. as measured by the fill level sensor 301). If the vaporisation tank 203 is, for example, $20\times 20\times 5\text{cm}$ (0.04m^2 surface area and 2L capacity) then the defrost process can only be 2.5 minutes with $80\text{cl}/\text{min}$ flow before the vaporisation tank 203 is completely full. When this happens (i.e. after the 2.5 minutes has elapsed) the defrost process is paused by lowering the threshold flow rate at which defrosting is triggered. This means that more frost will have to build up on the evaporator 222 (thus reducing the flow rate) until the new, lower threshold is met. For example, if the final flow rate is $0.17\text{m}^3/\text{min}$, the next defrost process may be triggered at $0.13\text{m}^3/\text{min}$ air flow.

[0048] In some examples, the ambient temperature,

relative humidity (RH), and other atmospheric conditions such as ambient air velocity may be used to determine when a next defrost process can be started. The ambient temperature, RH, and air speed may be measured by sensors not shown in the figures but well-known in the art. A combination of these values may be used to determine (an estimate of) the speed at which water will evaporate from the vaporisation tank 203. For example, vaporisation speed with $1\text{km}/\text{h}$ air flow (still weather) and 50C evaporation is around $0.5\text{kg}/\text{m}^2/\text{h}$ for 5C melted ice.

[0049] In a specific example, the previous defrost process introduced 1.8L of water into the vaporisation tank 203, and 0.02L evaporates each hour. After 80h, the air flow reaches the defrost process trigger threshold, and a new defrost process starts with the remaining 0.2L of water present. The maximum allowed defrosted water, air flow and next threshold will be adjusted accordingly.

[0050] It will be understood that the processor or processing system or circuitry referred to herein may in practice be provided by a single chip or integrated circuit or plural chips or integrated circuits, optionally provided as a chipset, an application-specific integrated circuit (ASIC), field-programmable gate array (FPGA), digital signal processor (DSP), graphics processing units (GPUs), etc. The chip or chips may comprise circuitry (as well as possibly firmware) for embodying at least one or more of a data processor or processors, a digital signal processor or processors, baseband circuitry and radio frequency circuitry, which are configurable so as to operate in accordance with the exemplary embodiments. In this regard, the exemplary embodiments may be implemented at least in part by computer software stored in (non-transitory) memory and executable by the processor, or by hardware, or by a combination of tangibly stored software and hardware (and tangibly stored firmware).

[0051] Reference is made herein to data storage for storing data. This may be provided by a single device or by plural devices. Suitable devices include for example a hard disk and non-volatile semiconductor memory.

[0052] Although at least some aspects of the embodiments described herein with reference to the drawings comprise computer processes performed in processing systems or processors, the invention also extends to computer programs, particularly computer programs on or in a carrier, adapted for putting the invention into practice. The program may be in the form of non-transitory source code, object code, a code intermediate source and object code such as in partially compiled form, or in any other non-transitory form suitable for use in the implementation of processes according to the invention. The carrier may be any entity or device capable of carrying the program. For example, the carrier may comprise a storage medium, such as a solid-state drive (SSD) or other semiconductor-based RAM; a ROM, for example a CD ROM or a semiconductor ROM; a magnetic recording medium, for example a floppy disk or hard disk; optical memory devices in general; etc.

[0053] The examples described herein are to be understood as illustrative examples of embodiments of the invention. Further embodiments and examples are envisaged. Any feature described in relation to any one example or embodiment may be used alone or in combination with other features. In addition, any feature described in relation to any one example or embodiment may also be used in combination with one or more features of any other of the examples or embodiments, or any combination of any other of the examples or embodiments. Furthermore, equivalents and modifications not described herein may also be employed within the scope of the invention, which is defined in the claims.

Claims

1. A method of controlling of defrosting of a refrigeration apparatus, the method comprising:
 - during a defrost process, detecting a flow rate of air through an item that is susceptible to frosting; and
 - stopping the defrost process in response to the detected air flow rate being greater than a threshold flow rate.
2. A method according to claim 1, comprising initiating the defrost process in response to a detected air flow rate through the item being less than a second threshold flow rate.
3. A method according to claim 1 or claim 2, comprising detecting a fill level of a vaporisation tank storing liquid water resulting from the defrost process, and wherein the defrost process is stopped in response to the detected fill level reaching a predetermined threshold fill level.
4. A method according to claim 1, comprising initiating the defrost process in response to a detected air flow rate through the item being less than a second threshold flow rate, detecting a fill level of a vaporisation tank storing liquid water resulting from the defrost process and stopping the defrost process in response to the detected fill level reaching a predetermined threshold fill level, wherein the second threshold flow rate is lowered in response to the detected fill level reaching the predetermined threshold fill level.
5. A method according to claim 3 or claim 4, wherein the fill level of the vaporisation tank is determined based on measuring a flow rate during the defrost process.
6. A method according to any of claims 3 to 5, wherein the fill level of the vaporisation tank is determined based on receiving data from a fill level sensor of the vaporisation tank.
7. A method according to any of claims 1 to 6, wherein the second threshold is equal to the first threshold.
8. A method according to any of claims 1 to 7, wherein measuring the air flow rate comprises activating a fan arranged to blow air through the item.
9. A method according to any of claims 1 to 8, wherein the air flow rate is measured periodically.
10. A refrigeration apparatus comprising:
 - a flow rate sensor for detecting a flow rate of air through an item that is susceptible to frosting; the refrigeration apparatus being configured to:
 - stop a defrost process being carried out by the refrigeration apparatus in response to the detected air flow rate being greater than a threshold flow rate.
11. A refrigeration apparatus according to claim 10, configured to initiate a defrost process in response to a detected air flow rate through the item being less than a second threshold flow rate.
12. A refrigeration apparatus according to claim 10 or claim 11, comprising a fan for blowing air through the item that is susceptible to frosting.
13. A refrigeration apparatus according to any of claims 10 to 12, wherein the refrigeration apparatus is configured to stop the defrost process in response to the detected fill level reaching a predetermined threshold fill level.
14. A refrigeration apparatus according to claim 13, wherein the refrigeration apparatus is configured to determine the fill level of the vaporisation tank based on measuring a flow rate during the defrost process.
15. A refrigeration apparatus according to claim 13 or claim 14, comprising a fill level sensor for detecting the fill level of a vaporisation tank.

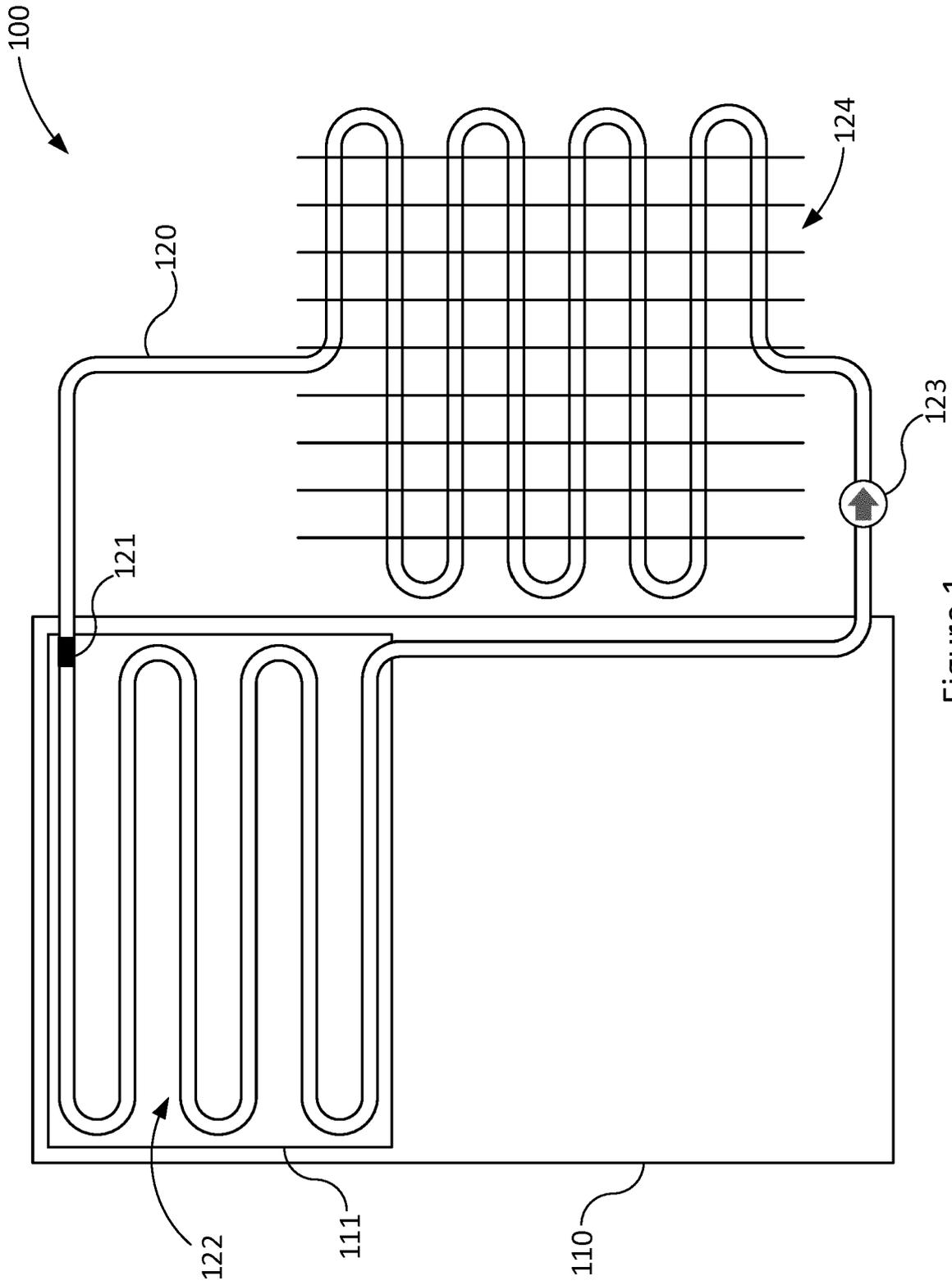


Figure 1
PRIOR ART

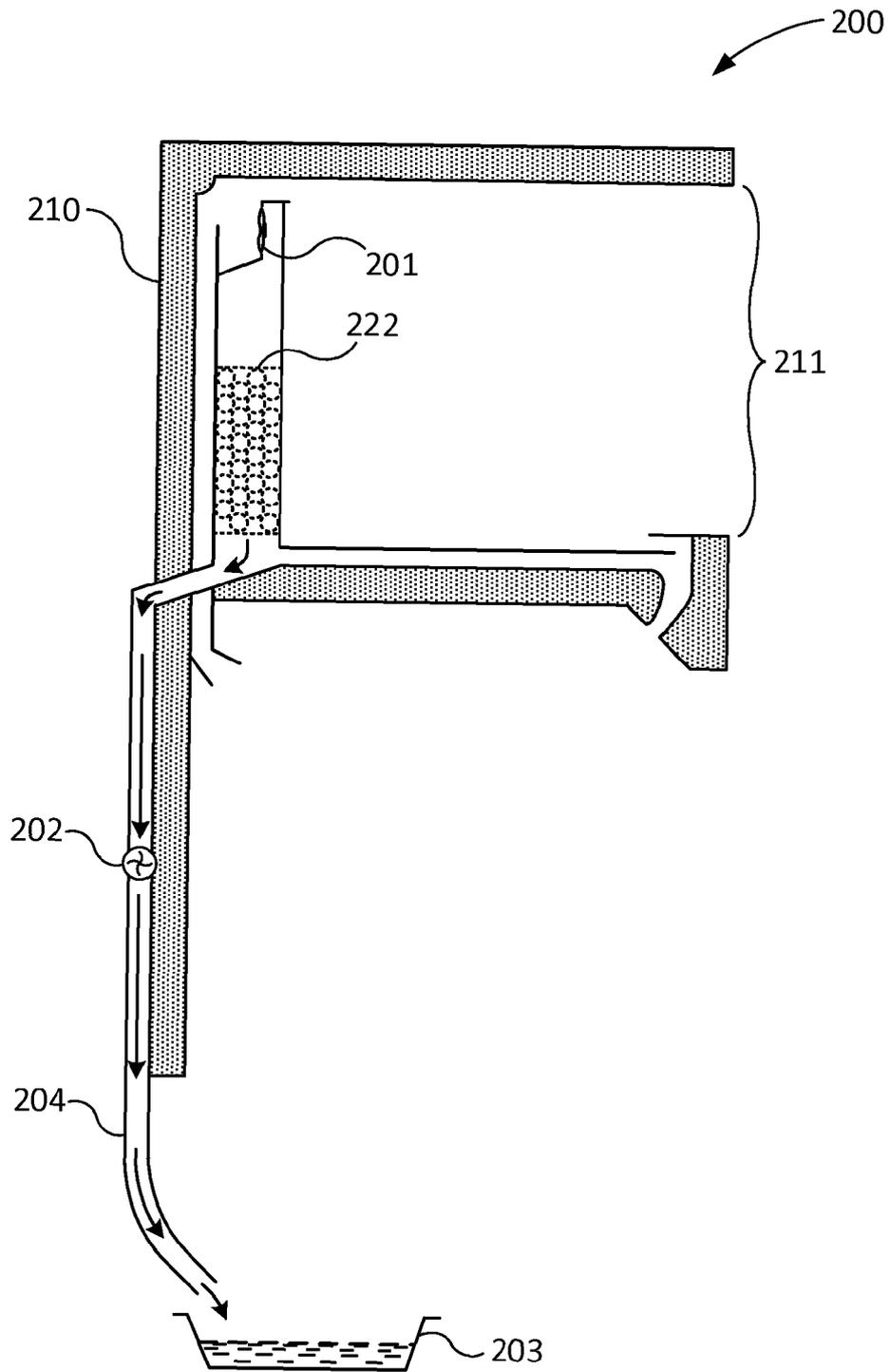


Figure 2

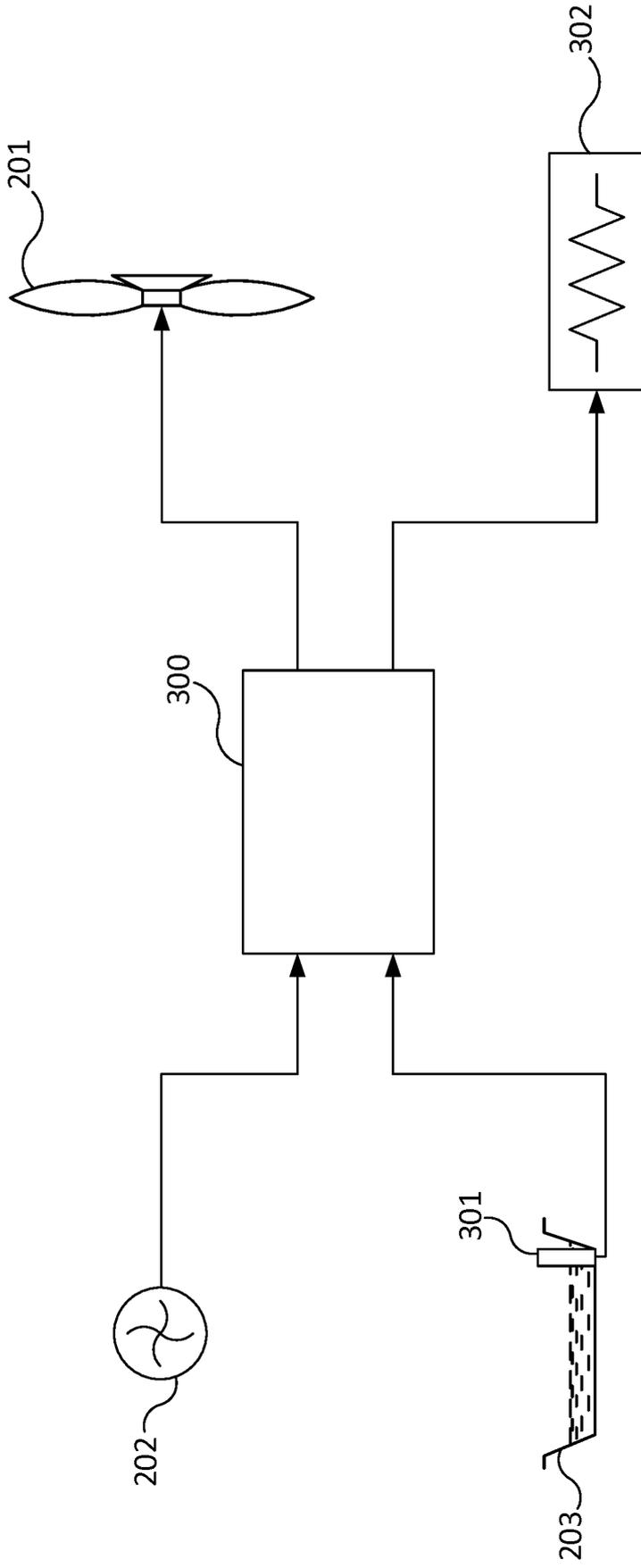


Figure 3



EUROPEAN SEARCH REPORT

Application Number
EP 17 20 8636

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Place of search The Hague		Date of completion of the search 18 June 2018	Examiner Yousufi, Stefanie
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- & : member of the same patent family, corresponding document	

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82