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(54) **TRANSPARENT ICE PRODUCTION SYSTEM AND METHOD**

(57) A method of making clear ice includes circulating a refrigerant through a refrigerant loop (238). A portion of the refrigerant loop (238) is in contact with a mold body (200). Thus, the refrigerant chills the mold body (200). The method also includes spraying a first volume of liquid water into a mold cavity (204,206) of the mold body (200). As a result, a first volume of ice is formed in the mold cavity (204,206). The method also includes spraying a second volume of liquid water into the mold cavity (204,206) after the first volume of ice has formed. Thus, a portion of the first volume of ice is melted and a second volume of ice is formed in mold cavity (204,206). The clear ice includes an unmelted portion of the first volume of ice and the second volume of ice.

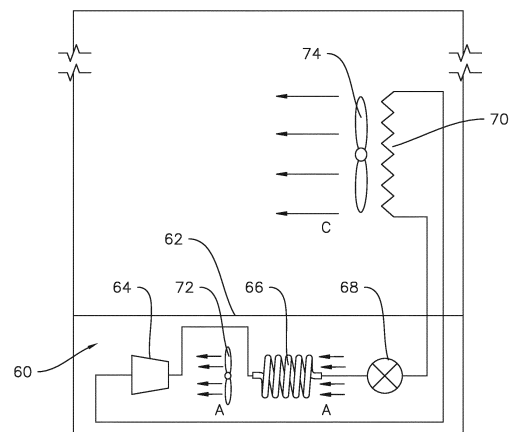


FIG. 2

EP 4 375 594 A1

Description

FIELD OF THE INVENTION

[0001] The present subject matter relates generally to ice making systems and methods, and more particularly, to systems and methods for making large clear ice.

BACKGROUND OF THE INVENTION

[0002] Certain refrigerator appliances include an ice-maker. To produce ice, liquid water is directed to the ice-maker and frozen. A variety of methods exist for freezing the water. In some systems a glycol refrigerant is used to cool the chamber in which the icemaker resides and a secondary refrigerant system is used to cool the glycol refrigerant.

[0003] Such a dual refrigerant system has certain drawbacks. For example, additional components are required for a second refrigerant system, raising overall operating costs. Some systems turn off elements of the refrigerant systems when there is no demand for ice to allay such costs. However, doing so may lead to the complication of glycol freezing in the refrigerant system, making it unable to flow when ice is required. In addition, such dual refrigerant systems have a high cooling capacity, leading to fast formation of ice. In forming ice quickly, impurities are trapped in the ice, leading it to have a cloudy or opaque appearance which may be undesirable to users who generally prefer clear ice.

[0004] Accordingly, an ice making assembly including a secondary refrigerant that forms clear ice would also be useful.

BRIEF DESCRIPTION OF THE INVENTION

[0005] Aspects and advantages of the invention will be set forth in part in the following description, or may be apparent from the description, or may be learned through practice of the invention.

[0006] In one example embodiment, a method of making clear ice is provided. The method includes circulating a refrigerant through a refrigerant loop. A portion of the refrigerant loop is in contact with a mold body. Thus, the refrigerant chills the mold body. The method also includes spraying a first volume of liquid water into a mold cavity of the mold body. As a result, a first volume of ice is formed in the mold cavity. The method also includes spraying a second volume of liquid water into the mold cavity after the first volume of ice has formed. Thus, a first portion of the first volume of ice is melted and a second volume of ice is formed in mold cavity. The clear ice includes a second, unmelted portion of the first volume of ice and the second volume of ice.

[0007] In another example embodiment, an ice making assembly is provided. The ice making assembly includes a refrigerant loop and a mold body having a mold cavity. The mold body is in contact with and in conductive ther-

mal communication with a portion of the refrigerant loop. Thus, circulating refrigerant through the refrigerant loop chills the mold body. The ice making assembly also includes a water pump coupled to a nozzle. The nozzle is positioned proximate to and aligned with the mold cavity such that the nozzle is configured to direct a spray of liquid water into the mold cavity. The ice making assembly further includes a controller. The controller is in operative communication with the water pump. The controller is configured to activate the water pump to spray a first volume of liquid water into a mold cavity of the mold body, such that a first volume of ice is formed in the mold cavity. The controller is also configured to activate the water pump to spray a second volume of liquid water into the mold cavity after the first volume of ice has formed. Thus, a first portion of the first volume of ice is melted and a second volume of ice is formed in the mold cavity. The clear ice includes a second, unmelted portion of the first volume of ice and the second volume of ice.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] A full and enabling disclosure of the present invention, including the best mode thereof, directed to one of ordinary skill in the art, is set forth in the specification, which makes reference to the appended figures.

FIG. 1 provides a perspective view of a refrigerator appliance according to one or more exemplary embodiments of the present subject matter.

FIG. 2 provides a schematic illustration of an example sealed cooling system as may be incorporated into a refrigerator appliance, such as the refrigerator appliance of FIG. 1, in one or more embodiments of the present subject matter.

FIG. 3 provides a perspective view of a door of the exemplary refrigerator appliance of FIG. 1.

FIG. 4 provides a schematic illustration of an ice making assembly according to one or more exemplary embodiments of the present subject matter.

FIG. 5 provides a schematic illustration of portions of the ice making assembly of FIG. 4.

FIG. 6 provides a flow chart of steps in an exemplary method in accordance with one or more exemplary embodiments of the present subject matter.

[0009] Repeat use of reference characters in the present specification and drawings is intended to represent the same or analogous features or elements of the present invention.

DETAILED DESCRIPTION

[0010] Reference now will be made in detail to embodiments of the invention, one or more examples of which are illustrated in the drawings. Each example is provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled

in the art that various modifications and variations can be made in the present invention without departing from the scope or spirit of the invention. For instance, features illustrated or described as part of one embodiment can be used with another embodiment to yield a still further embodiment. Thus, it is intended that the present invention covers such modifications and variations as come within the scope of the appended claims and their equivalents.

[0011] As used herein, the terms "first," "second," and "third" may be used interchangeably to distinguish one component from another and are not intended to signify location or importance of the individual components. The terms "includes" and "including" are intended to be inclusive in a manner similar to the term "comprising." Similarly, the term "or" is generally intended to be inclusive (i.e., "A or B" is intended to mean "A or B or both"). In addition, here and throughout the specification and claims, range limitations may be combined and/or interchanged. Such ranges are identified and include all the sub-ranges contained therein unless context or language indicates otherwise. For example, all ranges disclosed herein are inclusive of the endpoints, and the endpoints are independently combinable with each other. The singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise.

[0012] Approximating language, as used herein throughout the specification and claims, may be applied to modify any quantitative representation that could permissibly vary without resulting in a change in the basic function to which it is related. Accordingly, a value modified by a term or terms, such as "generally," "about," "approximately," and "substantially," are not to be limited to the precise value specified. In at least some instances, the approximating language may correspond to the precision of an instrument for measuring the value, or the precision of the methods or machines for constructing or manufacturing the components and/or systems. For example, the approximating language may refer to being within a 10 percent margin, i.e., including values within ten percent greater or less than the stated value. In this regard, for example, when used in the context of an angle or direction, such terms include within ten degrees greater or less than the stated angle or direction, e.g., "generally vertical" includes forming an angle of up to ten degrees in any direction, e.g., clockwise or counterclockwise, with the vertical direction V.

[0013] FIG. 1 provides a perspective view of a refrigerator appliance 100 according to an exemplary embodiment of the present subject matter. Refrigerator appliance 100 includes a cabinet or housing 120 that extends between a top portion 101 and a bottom portion 102 along a vertical direction V. Housing 120 defines chilled chambers for receipt of food items for storage. In particular, housing 120 defines a fresh food chamber 122 positioned at or adjacent top portion 101 of housing 120 and a freezer chamber 124 arranged at or adjacent bottom portion 102 of housing 120. As such, refrigerator appliance 100

is generally referred to as a "bottom mount refrigerator." It is recognized, however, that the benefits of the present disclosure apply to other types and styles of refrigerator appliances such as, e.g., a top mount refrigerator appliance or a side-by-side style refrigerator appliance, as well as stand-alone ice makers. Consequently, the description set forth herein is for illustrative purposes only and is not intended to be limiting in any aspect to any particular appliance or chilled chamber configuration.

[0014] Refrigerator doors 128 are rotatably hinged to an edge of housing 120 for selectively accessing fresh food chamber 122. In addition, a freezer door 130 is arranged below refrigerator doors 128 for selectively accessing freezer chamber 124. Freezer door 130 is coupled to a freezer drawer (not shown) slidably mounted within freezer chamber 124. Refrigerator doors 128 and freezer door 130 are shown in a closed configuration in FIG. 1.

[0015] Refrigerator appliance 100 also includes a dispensing assembly 140 for dispensing liquid water and/or ice. Dispensing assembly 140 includes a dispenser 142 positioned on or mounted to an exterior portion of refrigerator appliance 100, e.g., on one of doors 128. Dispenser 142 includes a discharging outlet 144 for accessing ice and liquid water. An actuating mechanism 146, shown as a paddle, is mounted below discharging outlet 144 for operating dispenser 142. In alternative exemplary embodiments, any suitable actuating mechanism may be used to operate dispenser 142. For example, dispenser 142 can include a sensor (such as an ultrasonic sensor) or a button rather than the paddle. A user interface panel 148 is provided for controlling the mode of operation. For example, user interface panel 148 includes a plurality of user inputs (not labeled), such as a water dispensing button and an ice-dispensing button, for selecting a desired mode of operation such as crushed or non-crushed ice.

[0016] Discharging outlet 144 and actuating mechanism 146 are an external part of dispenser 142 and are mounted in a dispenser recess 150. Dispenser recess 150 is positioned at a predetermined elevation convenient for a user to access ice or water and enabling the user to access ice without the need to bend-over and without the need to open doors 128. In the exemplary embodiment, dispenser recess 150 is positioned at a level that approximates the chest level of a user.

[0017] FIG. 2 provides a schematic view of the refrigerator appliance 100, in particular the sealed cooling system 60 thereof. As will be described in more detail below, the sealed cooling system 60 may also be a primary cooling loop in at least some embodiments. As illustrated in FIG. 2, refrigerator appliance 100 includes a machinery compartment 62 that at least partially contains components for executing a known vapor compression cycle for cooling air. The components include a compressor 64, a heat exchanger or condenser 66, an expansion device 68, and an evaporator 70 connected in series and charged with a refrigerant. Evaporator 70 is also a type

of heat exchanger which transfers heat from air passing over the evaporator to a refrigerant flowing through evaporator 70 thereby causing the refrigerant to vaporize. As such, cooled air C is produced and configured to refrigerate chambers 122 and 124 of refrigerator appliance 100. The cooled air C may be directed to the food storage chambers 122 and 124 by a fan 74.

[0018] From evaporator 70, vaporized refrigerant flows to compressor 64, which operates to increase the pressure of the refrigerant. This compression of the refrigerant raises its temperature, which is lowered by passing the gaseous refrigerant through condenser 66 where heat exchange with ambient air takes place so as to cool the refrigerant. A fan 72 is used to pull air across condenser 66, as illustrated by arrows A, so as to provide forced convection for a more rapid and efficient heat exchange between the refrigerant and the ambient air.

[0019] Expansion device 68 further reduces the pressure of refrigerant leaving condenser 66 before being fed as a liquid to evaporator 70. Collectively, the vapor compression cycle components in a refrigeration circuit, associated fans, and associated compartments are sometimes referred to as a sealed refrigeration system operable to force cold air through refrigeration chambers 122 and 124. The refrigeration system 60 depicted in FIG. 2 is provided by way of example only. It is within the scope of the present invention for other configurations of the refrigeration system to be used as well. For example, fan 74 may be repositioned so as to push air across evaporator 70, dual evaporators may be used with one or more fans, and numerous other configurations may be applied as well.

[0020] FIG. 3 provides a perspective view of a door of refrigerator doors 128. Refrigerator appliance 100 includes a sub-compartment 162 defined on refrigerator door 128. Sub-compartment 162 is often referred to as an "icebox." Sub-compartment 162 is positioned on refrigerator door 128 at or adjacent fresh food chamber 122. Thus, sub-compartment 162 may extend into fresh food chamber 122 when refrigerator door 128 is in the closed position. Access door 166 is hinged to refrigerator door 128. Access door 166 permits selective access to sub-compartment 162. Any manner of suitable latch 168 is configured with sub-compartment 162 to maintain access door 166 in a closed position. As an example, latch 168 may be actuated by a consumer in order to open access door 166 for providing access into sub-compartment 162. Access door 166 can also assist with insulating sub-compartment 162.

[0021] As may be seen in FIG. 4, refrigerator appliance 100 includes an ice making assembly 160, e.g., positioned or disposed at least partially within sub-compartment 162 (for example, the refrigerant loop described below may extend outside of the sub-compartment 162). It will be understood that while described in the context of refrigerator appliance 100, ice making assembly 160 can be used in any suitable refrigerator appliance or in a stand-alone icemaker. Thus, e.g., in alternative exem-

plary embodiments, ice making assembly 160 may be positioned at and mounted to other portions of housing 120, such as within various ice holding chambers including freezer chamber 124 or sub-compartment 162 may be fixed to a wall of housing 120 within fresh food chamber 122 rather than on refrigerator door 128.

[0022] As illustrated in FIG. 4, ice making assembly 160 employs a direct cooling system. A refrigerant may be circulated through a sealed refrigerant loop 238 (comprising lines 214, 218, and 222), as further described below. Thus, the sealed refrigerant loop 238 may be a secondary cooling loop, where the sealed cooling system 60 defines a primary cooling loop, as mentioned above. A portion 216 of the refrigerant loop 238 may be connected to or be situated in close proximity to a mold body 200 of ice making assembly 160, thereby effecting a direct (conductive) transfer of heat from mold body 200 to the refrigerant in the sealed refrigerant loop, e.g., thereby chilling the mold body 200 such that liquid water therein freezes to form ice.

[0023] The exemplary ice making assembly 160 illustrated in FIG. 4 generally includes a mold body 200 with one or more mold cavities defined therein, such as a first mold cavity 204 and a second mold cavity 206 as illustrated. Mold body 200 is illustrated in a dashed line outline in FIG. 4 in order to more clearly depict the shape of the mold cavities 204 and 206 therein. In some embodiments, for example as illustrated in FIG. 4, the mold cavities (and thus the ice pieces formed therein) may be gem-shaped, e.g., the mold cavities 204 and 206 may each define a multi-faceted non-Platonic solid shape.

[0024] As mentioned, the mold body 200 may be directly, e.g., conductively, cooled by the refrigerant loop 238. Thus, for example, the mold body 200 may be in contact with the refrigerant loop 238, such as with a portion 216 of the refrigerant loop 238, e.g., a portion of a connecting line 214 thereof which is downstream of a heat exchanger 224 and upstream of a refrigerant pump 220. In some embodiments, the mold body 200 may be in direct contact with the portion 216 of the refrigerant loop 238 without any intervening space or structures therebetween. In other embodiments, e.g., as illustrated in FIG. 4, a plate 202 may be provided which interposes the mold body 200 and the portion 216, and which is in direct contact with the mold body 200 on one side of the plate 202 and in direct contact with the portion 216 on the other, opposing, side of the plate 202. The plate 202, when provided, may promote more even distribution of thermal transfer between the portion 216 and the mold body 200, e.g., reducing or avoiding "cold spots" or pronounced temperature gradients across the top surface of the mold body 200.

[0025] The sealed refrigerant loop 238 may include a refrigerant pump 220 that is operable to urge the refrigerant therethrough. For example, activating the refrigerant pump 220 may cause the refrigerant to circulate through the sealed refrigerant loop 238, such as at a flow rate proportional to the operating speed of the refrigerant

pump 220. The refrigerant pump 220 may supply the refrigerant to a pressure line 222, which is connected to, e.g., coupled directly to, a first inlet 226 of a heat exchanger 224. The refrigerant in the sealed refrigerant loop 238 may travel through the heat exchanger 224 from the first inlet 226 to a first outlet 228. The heat exchanger 224 may also be coupled to the sealed system 60 (see also, FIG. 2), such as coupled to the sealed system 60 at a second inlet 230 into the heat exchanger 224 and at a second outlet 232 out of the heat exchanger 224. Thus, the refrigerant from the sealed system 60 (primary cooling loop) may flow through the heat exchanger 224 from the second inlet 230 to the second outlet 232 and, in so doing, the refrigerant from the sealed system 60 (primary cooling loop) may exchange thermal energy with, e.g., receive thermal energy from, the refrigerant in the sealed refrigerant loop 238 (secondary cooling loop), thereby reducing the temperature of the refrigerant in the sealed refrigerant loop 238. Also as shown in FIG. 4, the refrigerant from the sealed system 60 enters the heat exchanger 224 at the second inlet 230 in a direction as indicated by arrow 234 and flows out of the heat exchanger 224 at the second outlet 232 in a direction as indicated by arrow 236.

[0026] A connecting line 214 extends from the heat exchanger 224 to the mold body 200, where a portion 216 of the refrigerant loop 238 may be connected to the mold body 200 as described above. Thus, the refrigerant, having been cooled in the heat exchanger 224 as described above, draws heat from the mold body 200, e.g., chills the mold body 200 such that liquid water in the mold cavities 204 and 206 of the mold body 200 may form ice.

[0027] From the mold body 200, e.g., downstream of the portion 216 in contact with the mold body 200, the refrigerant in the sealed refrigerant loop 238 returns to the refrigerant pump 220 via a suction line 218.

[0028] Liquid water may be provided to the mold body 200 for generating ice therein via a water pump 212. For example, the water pump 212 may be coupled to one or more nozzles, such as one nozzle for each mold cavity 204 and 206 (and each mold cavity 204 and 206 being supplied by a single nozzle), e.g., as illustrated in FIG. 4, where the water pump 212 is coupled to a first nozzle 208 and a second nozzle 210. Further, in some embodiments, the water pump 212 may be a variable speed pump, and successive sprays of water into the mold body 200 may be provided at different speeds and/or different volumes of water may be provided in each spray. As illustrated, each nozzle 208 and 210 is positioned proximate to and below the corresponding mold cavity 204 and 206. Each nozzle 208 and 210 may further be aligned with, such as generally concentric with, the corresponding mold cavity 204 or 206, and may be proximate to the corresponding mold cavity 204 and 206 in that the nozzle 208 or 210 is close enough to the corresponding mold cavity 204 or 206 that the diameter of the spray or jet of liquid water emanating from the nozzle 208 or 210 is less than or equal to the diameter of the corresponding cavity

204 or 206 when the spray reaches the outermost (e.g., bottom) portion or side of the cavity 204 or 206 which is closest to the corresponding nozzle 208 or 210, e.g., the outermost portion of the first cavity 204 may be the open bottom end 240 (FIG. 5) and the outermost portion of the second cavity 206 may be the open bottom end 244 (FIG. 5).

[0029] While the features of ice making assembly 160 described above contribute to the formation of ice in mold body 200 generally, the production of clear ice in particular is promoted by slowing the formation of the ice in the mold body 200. For example, reducing and controlling the cooling capacity of the ice making assembly 160 may slow the rate of ice formation and thus remove impurities from the ice. Certain elements described above may be controlled for this purpose. For example, compressor 64 may be a variable speed compressor. During operation of ice making assembly 160, power to variable speed compressor 64 may be varied, e.g., increased or reduced, such as by operating the compressor 64 at a first speed followed by operating the compressor 64 at a second speed that is different from, e.g., less than, the first speed. For example, when the power to the variable speed compressor 64 of the primary cooling loop is reduced, such reduction results in reduced heat transfer in the heat exchanger 224 between the sealed system 60 (primary cooling loop) and the sealed refrigerant loop 238 (secondary cooling loop). By controlling the level of power provided to variable speed compressor 64, this rate of heat transfer may be controlled, thus providing the refrigerant through portion 216 at a temperature that is below freezing but warmer than conventional ice makers. For example, the refrigerant may circulate through connecting line 214, and portion 216 of line 214 in particular, at a temperature between about 10° F and about 30° F, such as between about 15° F and about 25° F, such as about 20° F. A warmer refrigerant in the refrigerant loop 238 may reduce the amount of heat transfer from water in mold body 200 and thus may slow the rate of ice formation in mold body 200.

[0030] Similarly, refrigerant pump 220 of ice making system 160 may be a variable speed pump. By reducing power to variable speed refrigerant pump 220, the rate of flow of the refrigerant through the sealed refrigerant loop 238 may be reduced, while increasing the power to the variable speed refrigerant pump 220 increases the rate of flow of the refrigerant through the sealed refrigerant loop 238. An increase in the flow rate of refrigerant through the sealed refrigerant loop 238 decreases the contact time in the heat exchanger 224 between the refrigerant in the sealed refrigerant loop 238 (secondary cooling loop) and the refrigerant in sealed system 60 (primary cooling loop), thus providing a warmer temperature in the refrigerant in the sealed refrigerant loop 238, particularly in the portion 216 of the refrigerant loop 238 that contacts the mold body 200, such as between about 10° F and about 30° F, such as between about 15° F and about 25° F, such as about 20° F, as noted above. When

the refrigerant in the portion 216 of the sealed refrigerant loop 238 is at such temperatures, it provides a rate of heat transfer from water in mold body 200 and thus a rate of ice formation in mold body 200 which is conducive to clear ice formation, e.g., a slower rate of heat transfer and of ice formation.

[0031] In some embodiments, the gradual formation of clear ice may also or instead be promoted by forming a relatively small volume, e.g., less than the entire volume of the cavity, of ice at a time. For example, the mold cavity, e.g., cavity 204 (or cavities, e.g., 204 and 206, in embodiments with more than one cavity), may be filled with successive sprays of liquid water from the corresponding nozzle(s) 208 and/or 210. Thus, some embodiments of the present disclosure may include spraying a first volume of liquid water into a mold cavity of the mold body to form a first volume of ice in the mold cavity, followed by spraying one or more subsequent volumes of liquid water into the mold cavity, such as spraying a second volume of liquid water into the mold cavity after the first volume of ice has formed, spraying a third volume of liquid water, etc. Spraying the subsequent volume of liquid water may result in partial melting of the previously formed volume of ice, such as spraying the second volume of liquid water into the mold cavity after the first volume of ice has formed may result in a portion of the first volume of ice being melted, such as an outer (closest to the opening 240 or 244 of the mold cavity 204 or 206) surficial portion of the first volume of ice being melted when it contacts the sprayed liquid water. Subsequent sprays of liquid water and partial (surficial) melting of the previously formed ice may result in smoother ice when the mold cavity is filled. For example, the initial (first) volume of ice may have a rough texture due to the spray pattern, whereas the successive partial melts and fusing with additional volumes of ice formed from the subsequent sprays of liquid water gradually smooths the finished surface of the total ice volume after each spray. Thus, for example, the second (and/or other subsequent) volume of liquid water may melt a portion of the first (and/or other previous) volume of ice and form a second volume of ice. The remaining, unmelted, portion of the first volume of ice combines with (e.g., bonds to along the outermost, e.g., lower, boundary of the first volume of ice) the second volume of ice to form the clear ice, and the clear ice may further include additional layers formed from additional subsequent sprays of liquid water by the same process, e.g., a third spray of liquid water that partially melts the second volume of ice and forms a third volume of ice bonded to the second and first volumes of ice, etc. Thus, the final product, e.g., the clear ice produced by the ice making assembly 160, thereby includes the first volume of ice, or at least the unmelted portion thereof, and the second volume of ice (as well as additional volumes of ice formed from additional subsequent spray of liquid water, if any).

[0032] As may be seen in FIG. 5, the mold cavity or each mold cavity extends along the vertical direction V

from an open bottom end to an enclosed top end. For example, the first mold cavity 204 extends vertically from an open bottom end 240 to an enclosed top end 242, and is enclosed within the mold body 200 on all sides between the bottom end 240 and the top end 242. Similarly, the second mold cavity 206 extends vertically from an open bottom end 244 to an enclosed top end 246, and is enclosed within the mold body 200 on all sides between the bottom end 244 and the top end 246. Also as may be seen in FIGS. 4 and 5, the nozzles 208 and 210 are positioned below the corresponding cavities 204 and 206, such that the liquid water is sprayed generally upwards, against the force of gravity, into the mold cavity or cavities. Thus, a portion of each spray of liquid water that does not form the corresponding volume of ice (e.g., a portion of the first volume of liquid water that does not form part of the first volume of ice), as well as the melted portion of any previously-formed volume of ice, drains back out of the mold cavity or cavities by gravity.

[0033] As illustrated in FIGS. 4 and 5, the top, uppermost portion of the mold body 200 is in closest contact with the portion 216 of the refrigerant loop 238 relative to the remainder of the mold body 200. Thus, the upper portion of the mold body 200 will be coldest, e.g., colder than lower portion of the mold body 200. For example, the top surfaces 242 and 246 of the mold cavities 204 and 206, being positioned closest to the portion 216, will be the coldest portion of the mold cavities 204 and 205. Therefore, the first spray of liquid water into the mold cavity or each mold cavity 204 and/or 206 may experience the coldest temperature, e.g., lower temperature than subsequently sprayed volumes of liquid water. Accordingly, the operating speed or speeds of the compressor 64 in the primary cooling loop and of the refrigerant pump 220 in the secondary cooling loop affect mold body temperature and cooling capacity. Thus, the speeds of the compressor 64 and/or the refrigerant pump 220 may be optimized for making clear ice. In some embodiments, in order to promote slower rate of freezing and thus clear ice formation, the temperature of the refrigerant in the refrigerant loop 238 may be adjusted corresponding to the sequence of liquid water volume spraying. For example, the refrigerant may be circulated through the refrigerant loop 238 at a first subfreezing temperature while spraying the first volume of liquid water and the refrigerant may then be circulated through the refrigerant loop at a second subfreezing temperature less than the first subfreezing temperature while spraying the second volume of liquid water. The first subfreezing temperature may be, for example, between about 20° F and about 30° F, such as about 25° F, while the second subfreezing temperature may be, for example, between about 15° F and about 25° F, such as about 20° F. The temperature of the refrigerant in the refrigerant loop may be controlled by any one or more of the techniques described above, e.g., by controlling the speed of the refrigerant pump 220 of the secondary cooling loop and/or the compressor 64 of the primary cooling loop.

[0034] Turning now to FIG. 6, embodiments of the present disclosure also include methods of making clear ice, such as the exemplary method 400 of making clear ice illustrated in FIG. 6. Such methods may be used with ice making assemblies such as the ice making assembly 160 illustrated, e.g., in FIGS. 4 and 5, and described above, however, methods of making clear ice according to various embodiments of the present disclosure are not necessarily limited to the specific ice making assembly shown and described. For illustrative purposes, reference numbers used herein in the context of icemaking assembly 160 will also be used to describe example method embodiments.

[0035] As illustrated in FIG. 6, the method 400 may include a step 410 of circulating a refrigerant through a refrigerant loop, such as loop 238, e.g., the secondary cooling loop, to chill a mold body, e.g., mold body 200. For example, a portion 216 of the refrigerant loop 238 may be in contact with the mold body 200, whereby the refrigerant in the refrigerant loop 238, and in particular in the portion 216 thereof, chills the mold body 200. The portion 216 may be in direct or indirect contact with the mold body 200, such as indirect contact via the plate 202 as described above.

[0036] Method 400 may also include a step 420 of spraying a first volume of liquid water into a mold cavity 204 of the mold body 200. As a result of such spraying, a first volume of ice is formed in the chilled mold cavity 204, e.g., where the mold cavity 204 is or was chilled by the refrigerant in the refrigerant loop 238.

[0037] The method 400 may further include a step 430 of spraying a second volume of liquid water into the mold cavity 204 after the first volume of ice has formed. As a result of spraying the second volume of liquid water, a portion of the first volume of ice is melted and a second volume of ice is formed in mold cavity 204. The clear ice made in the method 400 includes both the first volume of ice (or at least the unmelted portion thereof) and the second volume of ice.

[0038] The circulating step 410 may be performed before and/or during one or both of the spraying steps 420 and 430. For example, the circulating step 410 may be performed during both spraying steps 420 and 430, and may further include circulating the refrigerant through the refrigerant loop 238 at a first subfreezing temperature while spraying the first volume of liquid water and circulating the refrigerant through the refrigerant loop at a second subfreezing temperature less than the first subfreezing temperature while spraying the second volume of liquid water. In some embodiments, the temperature of the refrigerant may be controlled by the pumping speed, e.g., the refrigerant may be circulated through the refrigerant loop 238 by a refrigerant pump 220, and the step 410 of circulating the refrigerant through the refrigerant loop 238 may include circulating the refrigerant through the refrigerant loop 238 at a first speed while spraying the first volume of liquid water and circulating the refrigerant through the refrigerant loop 238 at a second speed dif-

ferent from, e.g., less than, the first speed while spraying the second volume of liquid water. Further the step 410 of circulating the refrigerant through the refrigerant loop 238 may include circulating the refrigerant through a heat exchanger 224 coupled to the refrigerant loop 238, thereby cooling the refrigerant as the refrigerant passes through the heat exchanger 238. Thus, for example, when the flow rate of the refrigerant through the refrigerant loop 238, and in particular through the heat exchanger 224 between the first inlet 226 and the first outlet 228 thereof, is changed, e.g., reduced, the increased contact time or reaction time in the heat exchanger 224 may result in a lower temperature of the refrigerant in the refrigerant loop 238, as described above.

[0039] In some embodiments which include the heat exchanger 224, the heat exchanger 224 may be in thermal communication with a sealed cooling system, e.g., sealed cooling system 60, and the sealed cooling system 60 may include a compressor 64. In such embodiments, the method 400 may also include operating the compressor 64 at a first speed while spraying the first volume of liquid water and operating the compressor 64 at a second speed different from, e.g., greater than, the first speed while spraying the second volume of liquid water. As described above, the increased flow rate in the sealed cooling system 60 may result in an increased cooling capacity of the sealed cooling system 60, which may thereby lead to a lower temperature of the refrigerant in the sealed refrigerant loop 238 when the speed of the compressor 64 increases.

[0040] As mentioned above, in some embodiments, the mold body 200 may include more than one mold cavity. For example, the mold cavity may be a first mold cavity 204 of the mold body 200, and the mold body 200 may further include a second mold cavity 206. In such embodiments, the first volume of liquid water may be the only liquid water supplied to the mold body 200 during the step 420 of spraying the first volume of liquid water and the first volume of liquid water may be sprayed only into the first mold cavity 204 (and not into the second mold cavity 206 or any other mold cavity). Further, in such embodiments, the second volume of liquid water may be the only liquid water supplied to the mold body 200 during the step 430 of spraying the second volume of liquid water and the second volume of liquid water may be sprayed only into the first mold cavity 204 (and not into the second mold cavity 206 or any other mold cavity).

[0041] In particular embodiments, the liquid water may be provided, e.g., sprayed, to only one single mold cavity when the ice making assembly 160 and/or a refrigerator appliance 100 into which the ice making assembly 160 is incorporated is in an energy saving mode. For example, the energy saving mode may be initiated by a controller of the ice making assembly and/or refrigerator appliance in response to a signal or input received from or by a user input, e.g., a button, on the user interface panel 148.

[0042] In particular embodiments, the liquid water may be provided, e.g., sprayed, to only one single mold cavity

when a demand for ice is low. For example, a low demand for ice may be identified or determined by a controller of the ice making assembly 160 and/or a refrigerator appliance 100 into which the ice making assembly 160 is incorporated based on a level sensor in operative communication with an ice bucket or ice bin which receives ice produced by the mold body 200 and/or ice making assembly 160. For example, the level sensor may be an optical sensor. As another example, the level sensor may be a lever bar. In such embodiments, the low demand for ice may be determined in response to a signal from the level sensor. For example, the signal may take the form of an input generated in response to a vertical position of the hinged lever bar. The hinged lever bar may rest on top of ice collected in the ice bucket, and, as ice is used, the height of the combined ice lowers, causing the hinged lever bar to rotate about its hinge. In contrast, when the demand for ice is low and the hinged lever bar remains in an elevated position, the ice production may be delayed or reduced, such as by providing liquid water to less than all of the mold cavities, such as only one mold cavity, or to only two mold cavities in embodiments where the mold body 200 includes more than two mold cavities, etc. Thus, the low demand for ice may be determined in response to a lack of change, or a change below a predetermined threshold, in a signal from the level sensor.

[0043] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they include structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

Claims

1. A method of making clear ice, comprising the steps of:

circulating a refrigerant through a secondary cooling loop, wherein a portion of the secondary cooling loop is in contact with a mold body, whereby the refrigerant chills the mold body; spraying a first volume of liquid water into a mold cavity of the mold body, whereby a first volume of ice is formed in the mold cavity; and spraying a second volume of liquid water into the mold cavity after the first volume of ice has formed, whereby a first portion of the first volume of ice is melted and a second volume of ice is

formed in mold cavity, wherein the clear ice comprises a second, unmelted portion of the first volume of ice and the second volume of ice.

2. The method of claim 1, wherein the refrigerant is circulated through the secondary cooling loop at a first subfreezing temperature while spraying the first volume of liquid water and the refrigerant is circulated through the secondary cooling loop at a second subfreezing temperature less than the first subfreezing temperature while spraying the second volume of liquid water.
3. The method of claim 1, wherein the refrigerant is circulated through the secondary cooling loop by a refrigerant pump, wherein the step of circulating the refrigerant through the secondary cooling loop comprises circulating the refrigerant through the secondary cooling loop at a first speed while spraying the first volume of liquid water and circulating the refrigerant through the secondary cooling loop at a second speed different from the first speed while spraying the second volume of liquid water.
4. The method of claim 1, wherein circulating the refrigerant through the secondary cooling loop comprises circulating the refrigerant through a heat exchanger coupled to the secondary cooling loop, thereby cooling the refrigerant as the refrigerant passes through the heat exchanger.
5. The method of claim 4, wherein the heat exchanger is in thermal communication with a primary cooling loop, the primary cooling loop comprising a compressor, the method further comprising operating the compressor at a first speed while spraying the first volume of liquid water and operating the compressor at a second speed different from the first speed while spraying the second volume of liquid water.
6. The method of claim 1, wherein the mold cavity is a first mold cavity of the mold body, the mold body further comprising a second mold cavity, wherein the first volume of liquid water is the only liquid water supplied to the mold body during the step of spraying the first volume of liquid water and is sprayed only into the first mold cavity, and wherein the second volume of liquid water is the only liquid water supplied to the mold body during the step of spraying the second volume of liquid water and is sprayed only into the first mold cavity.
7. The method of claim 6, wherein the first volume of water is sprayed only into the first mold cavity and the second volume of water is sprayed only into the first mold cavity when in an energy saving mode.

8. The method of claim 6, further comprising determining that a demand for ice is low before spraying the first volume of liquid water and before spraying the second volume of liquid water.
9. The method of claim 1, wherein the first volume of liquid water and the second volume of liquid water are sprayed from a nozzle positioned below the mold body, whereby a portion of the first volume of liquid water that does not form the first volume of ice drains out of the mold cavity by gravity, and whereby a portion of the second volume of liquid water that does not form the second volume of ice drains out of the mold cavity by gravity.
10. An ice making assembly operable to generate clear ice, the ice making assembly comprising:
 - a secondary cooling loop;
 - a mold body comprising a mold cavity, the mold body in contact with and in conductive thermal communication with a portion of the secondary cooling loop, whereby circulating refrigerant through the secondary cooling loop chills the mold body;
 - a water pump coupled to a nozzle, the nozzle positioned proximate to and aligned with the mold cavity whereby the nozzle is configured to direct a spray of liquid water into the mold cavity; and
 - a controller, the controller in operative communication with the water pump, the controller configured to:
 - activate the water pump to spray a first volume of liquid water into a mold cavity of the mold body, whereby a first volume of ice is formed in the mold cavity; and
 - activate the water pump to spray a second volume of liquid water into the mold cavity after the first volume of ice has formed, whereby a first portion of the first volume of ice is melted and a second volume of ice is formed in the mold cavity, wherein the clear ice comprises a second, unmelted portion of the first volume of ice and the second volume of ice.
11. The ice making assembly of claim 10, further comprising a refrigerant pump coupled to the secondary cooling loop and in operative communication with the controller, wherein the controller is further configured to operate the refrigerant pump at a first speed while spraying the first volume of liquid water and to operate the refrigerant pump at a second speed different from the first speed while spraying the second volume of liquid water.
12. The ice making assembly of claim 10, further comprising a heat exchanger coupled to the secondary cooling loop, the heat exchanger operable to cool refrigerant circulating in the secondary cooling loop as the refrigerant passes through the heat exchanger.
13. The ice making assembly of claim 12, wherein the heat exchanger is in thermal communication with a primary cooling loop, the primary cooling loop comprising a compressor, and wherein the controller is further configured to operate the compressor at a first speed while spraying the first volume of liquid water and to operate the compressor at a second speed different from the first speed while spraying the second volume of liquid water.
14. The ice making assembly of claim 10, wherein the mold cavity is a first mold cavity of the mold body, the mold cavity further comprising a second mold cavity, wherein the controller is configured to activate the water pump to spray only the first volume of liquid water and only into the first mold cavity, and wherein the controller is configured to activate the water pump to spray only the second volume of liquid water and only into the first mold cavity.
15. The ice making assembly of claim 14, wherein the controller is configured to spray the first volume of liquid water only into the first mold cavity and the second volume of water only into the first mold cavity in response to an energy saving mode input.
16. The ice making assembly of claim 14, wherein the controller is further configured to determine that a demand for ice is low before spraying the first volume of liquid water and before spraying the second volume of liquid water.
17. The ice making assembly of claim 10, further comprising a nozzle positioned below the mold body, wherein activating the water pump causes the first volume of liquid water and the second volume of liquid water to be sprayed from the nozzle whereby a portion of the first volume of liquid water that does not form the first volume of ice drains out of the mold cavity by gravity, and whereby a portion of the second volume of liquid water that does not form the second volume of ice drains out of the mold cavity by gravity.

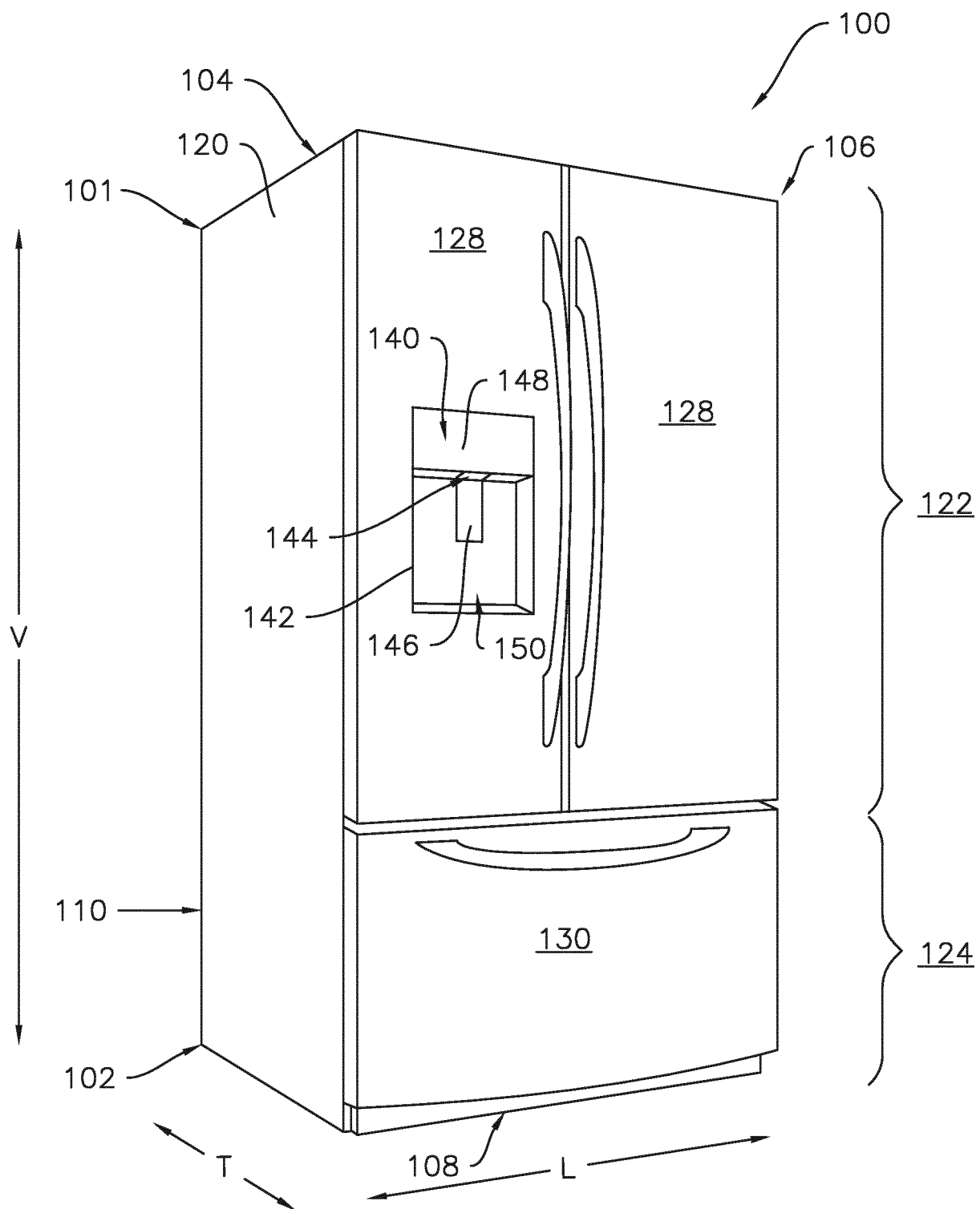


FIG. 1

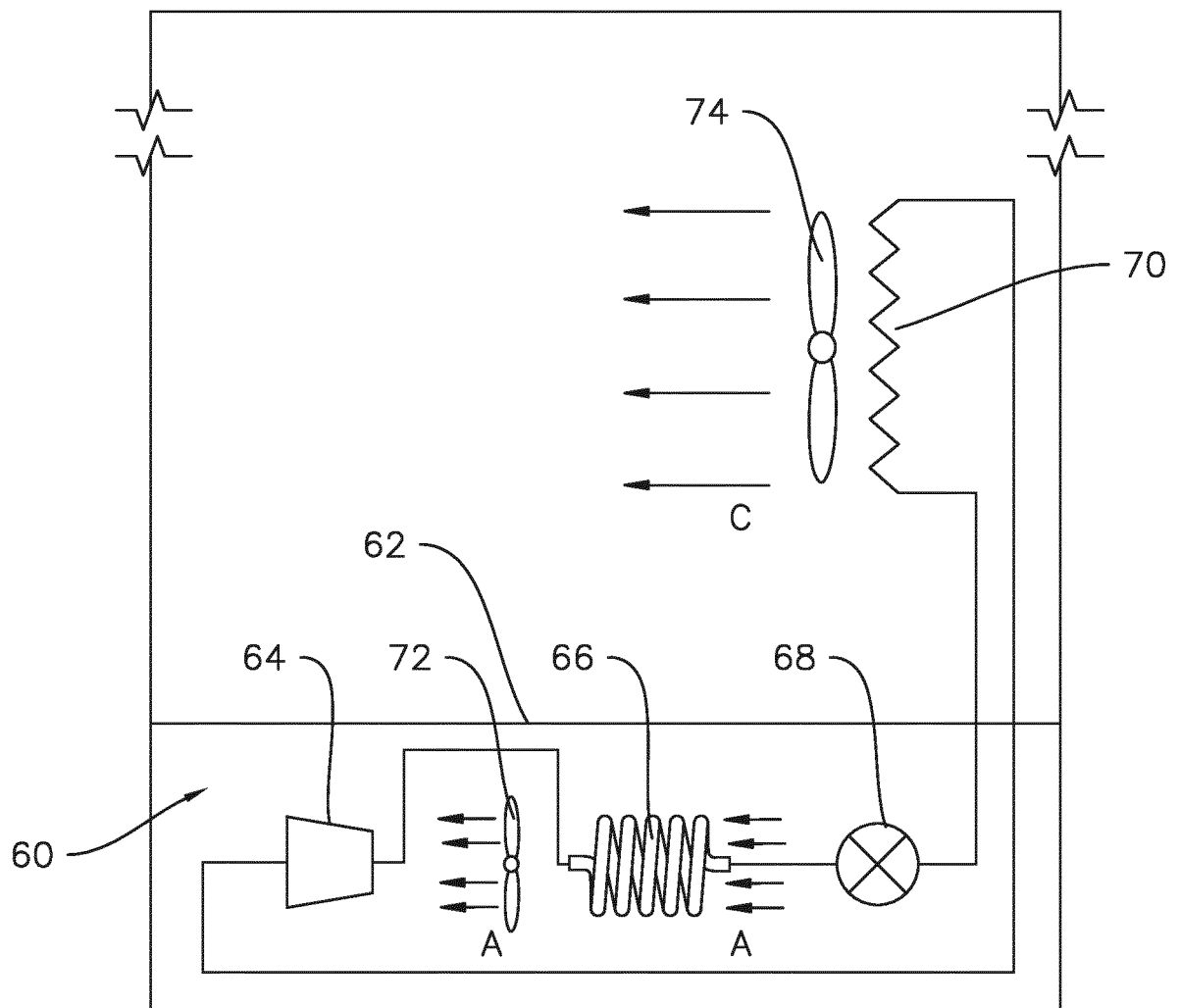


FIG. 2

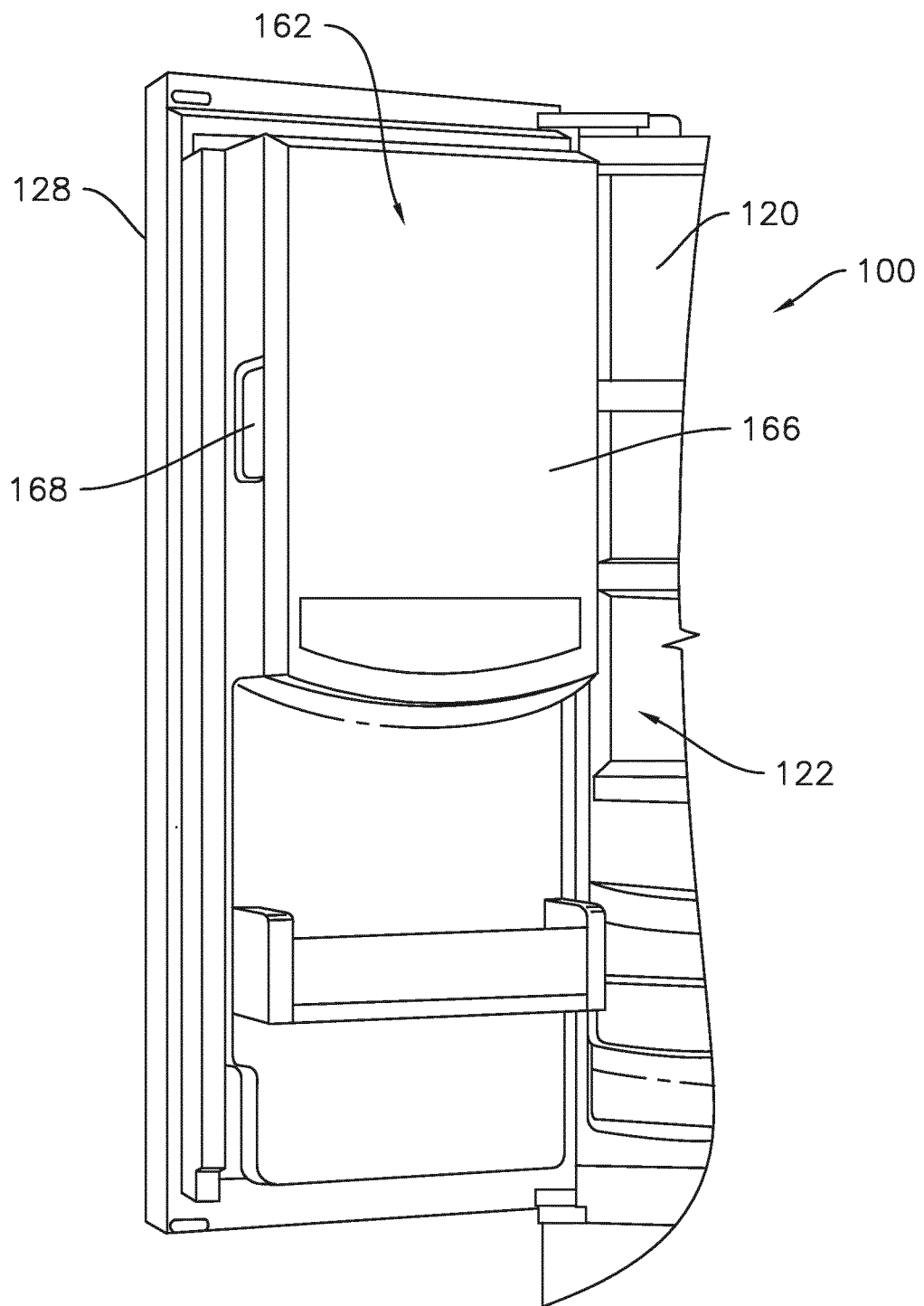


FIG. 3

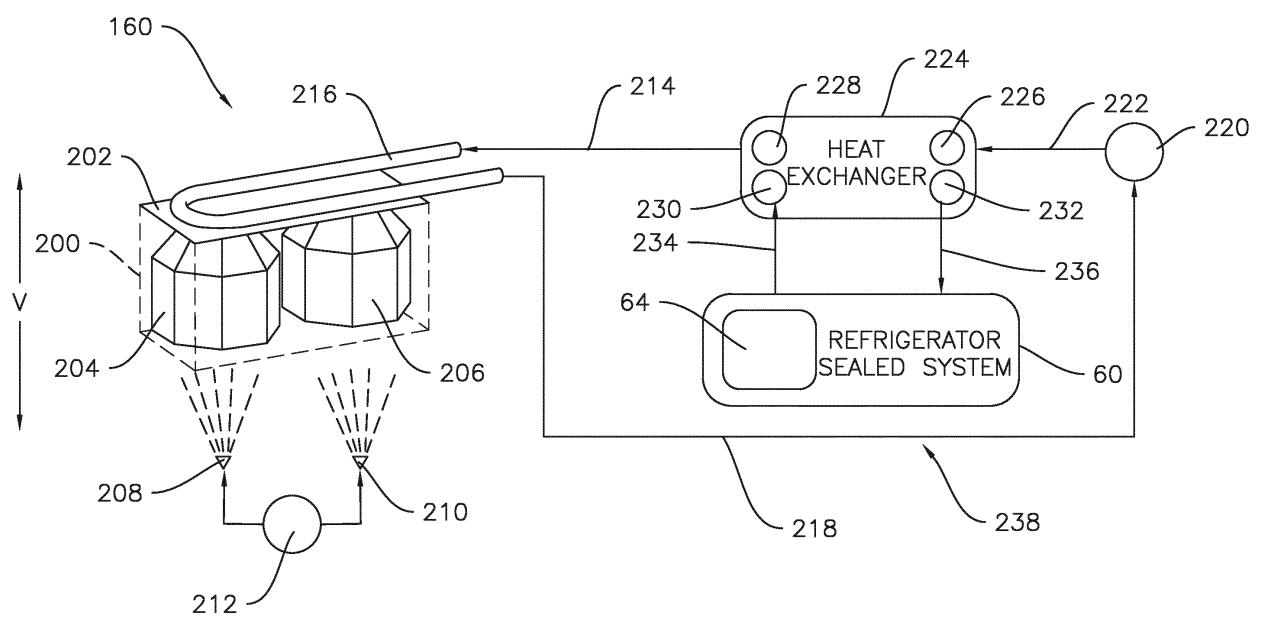


FIG. 4

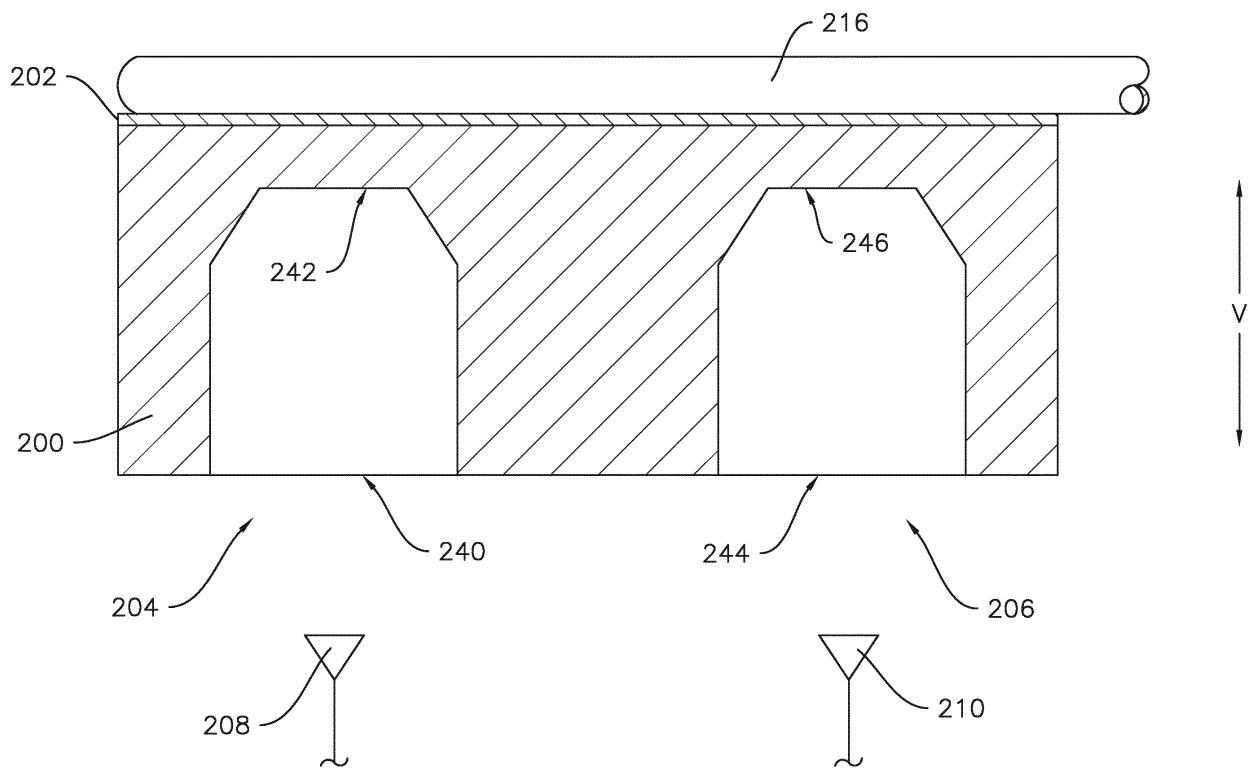


FIG. 5

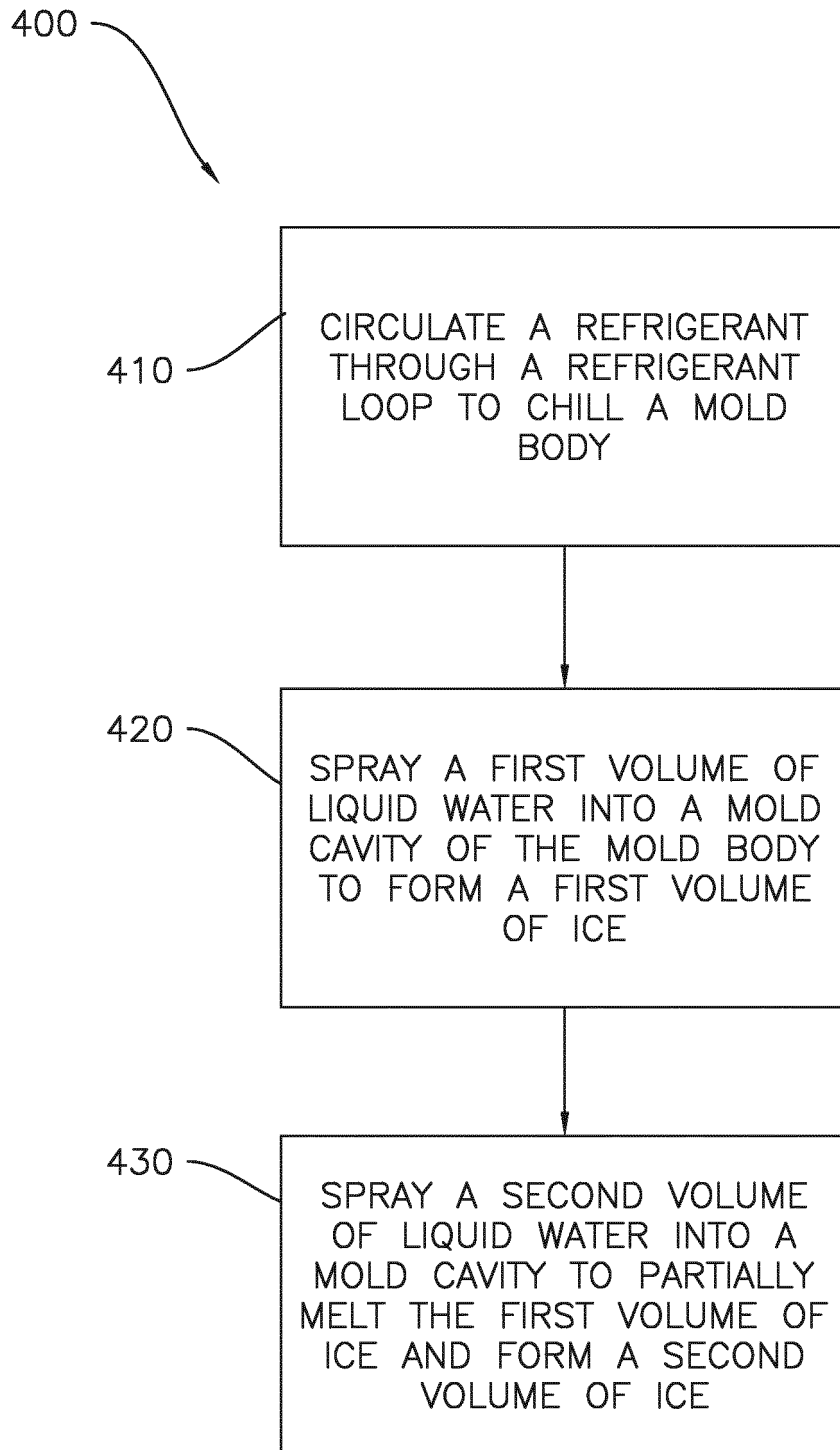


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.

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A. CLASSIFICATION OF SUBJECT MATTER F25C 1/18(2006.01)i According to International Patent Classification (IPC) or to both national classification and IPC																					
B. FIELDS SEARCHED																					
Minimum documentation searched (classification system followed by classification symbols) F25C1																					
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched																					
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) CNTXT, WPABS, ENTXTC, CJFD: 海尔, 蒸发器, 透明冰, 层, 载冷, 二次, 热交换器, 换热器, 喷嘴, 喷射, spray, nozzle																					
C. DOCUMENTS CONSIDERED TO BE RELEVANT																					
<table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>Y</td> <td>CN 2697536 Y (HEFEI MEILING COMPANY LIMITED) 04 May 2005 (2005-05-04) description, specific embodiments, and figures 1-2</td> <td>1, 4, 6-10, 12, 14-17</td> </tr> <tr> <td>Y</td> <td>CN 103353196 A (TIANJIN UNIVERSITY) 16 October 2013 (2013-10-16) description, paragraph 5, and figures 1-2</td> <td>1, 4, 6-10, 12, 14-17</td> </tr> <tr> <td>A</td> <td>CN 112567190 A (QINGDAO HAIER REFRIGERATOR CO., LTD. et al.) 26 March 2021 (2021-03-26) entire document</td> <td>1-17</td> </tr> <tr> <td>A</td> <td>CN 112254389 A (JIAXING BUKE REFRIGERATION EQUIPMENT CO., LTD.) 22 January 2021 (2021-01-22) entire document</td> <td>1-17</td> </tr> <tr> <td>A</td> <td>CN 112469950 A (QINGDAO HAIER REFRIGERATOR CO., LTD. et al.) 09 March 2021 (2021-03-09) entire document</td> <td>1-17</td> </tr> <tr> <td>A</td> <td>WO 2020122443 A1 (LG ELECTRONICS INC.) 18 June 2020 (2020-06-18) entire document</td> <td>1-17</td> </tr> </tbody> </table>	Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	Y	CN 2697536 Y (HEFEI MEILING COMPANY LIMITED) 04 May 2005 (2005-05-04) description, specific embodiments, and figures 1-2	1, 4, 6-10, 12, 14-17	Y	CN 103353196 A (TIANJIN UNIVERSITY) 16 October 2013 (2013-10-16) description, paragraph 5, and figures 1-2	1, 4, 6-10, 12, 14-17	A	CN 112567190 A (QINGDAO HAIER REFRIGERATOR CO., LTD. et al.) 26 March 2021 (2021-03-26) entire document	1-17	A	CN 112254389 A (JIAXING BUKE REFRIGERATION EQUIPMENT CO., LTD.) 22 January 2021 (2021-01-22) entire document	1-17	A	CN 112469950 A (QINGDAO HAIER REFRIGERATOR CO., LTD. et al.) 09 March 2021 (2021-03-09) entire document	1-17	A	WO 2020122443 A1 (LG ELECTRONICS INC.) 18 June 2020 (2020-06-18) entire document	1-17
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Date of the actual completion of the international search 26 September 2022																					
Date of mailing of the international search report 10 October 2022																					
Name and mailing address of the ISA/CN China National Intellectual Property Administration (ISA/CN) No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088, China Facsimile No. (86-10)62019451																					
Authorized officer Telephone No.																					

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2022/106347

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C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 112240658 A (QINGDAO HAIER REFRIGERATOR CO., LTD. et al.) 19 January 2021 (2021-01-19) entire document	1-17

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2022/106347

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
CN 2697536 Y	04 May 2005	None	
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CN 112567190 A	26 March 2021	WO 2020029948 A1	13 February 2020
		EP 3833913 A1	16 June 2021
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