



(11)

**EP 4 116 645 A1**

(12)

**EUROPEAN PATENT APPLICATION**

published in accordance with Art. 153(4) EPC

(43) Date of publication:  
**11.01.2023 Bulletin 2023/02**

(51) International Patent Classification (IPC):  
**F25C 1/18** (2006.01)

(21) Application number: **21765258.5**

(52) Cooperative Patent Classification (CPC):  
**F25C 1/20; F25C 1/10; F25C 2600/04**

(22) Date of filing: **23.02.2021**

(86) International application number:  
**PCT/CN2021/077331**

(87) International publication number:  
**WO 2021/175129 (10.09.2021 Gazette 2021/36)**

(84) Designated Contracting States:  
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB  
 GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO  
 PL PT RO RS SE SI SK SM TR**  
 Designated Extension States:  
**BA ME**  
 Designated Validation States:  
**KH MA MD TN**

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(30) Priority: 04.03.2020 US 202016808514

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## (54) ICE MAKING ASSEMBLY AND OPERATING METHOD THEREFOR

(57) An ice making assembly includes a central hub rotatably mounted within a chilled chamber. A mold assembly is attached to the central hub and includes an ice mold that is pivotally coupled to a yoke and defines a mold cavity for receiving water. A drive mechanism ro-

tates the central hub by the following approach: accelerating the central hub until the rotation speed reaches a target speed and periodically reducing the rotation speed of the central hub to a reduced speed before accelerating back to the target speed until an ice billet is formed.

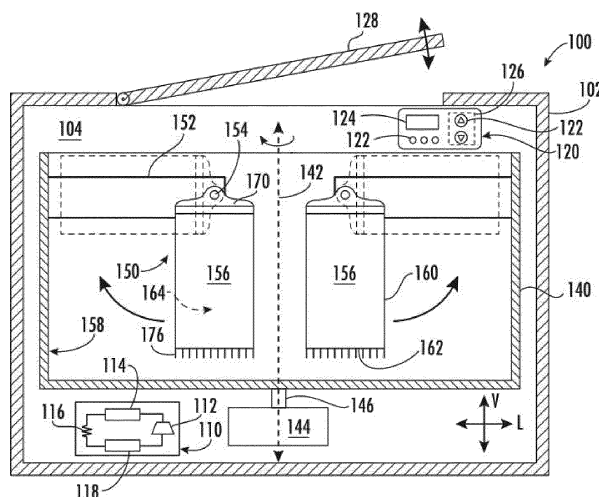


FIG.1

## Description

### FIELD OF THE INVENTION

**[0001]** The present subject matter relates generally to ice making assemblies, and more particularly to ice making assemblies that use centrifugal force to create clear billets of ice.

### BACKGROUND OF THE INVENTION

**[0002]** In domestic and commercial applications, ice is often formed as solid cubes, such as crescent cubes or generally rectangular blocks. Specifically, certain ice makers include a freezing mold that defines a plurality of cavities that can be filled with liquid water, and such liquid water can freeze within the plurality of cavities to form solid ice cubes. Typical solid cubes or blocks may be relatively small in order to accommodate a large number of uses, such as temporary cold storage and rapid cooling of liquids in a wide range of sizes.

**[0003]** In typical ice making appliances, water in the cavities begins to freeze and solidify first from its sides and outer surfaces (including a top water surface that may be directly exposed to freezing air), and then in and through the remaining volume of water occupying the cavity. In other words, the exterior surfaces of an ice cube freeze first. However, impurities and gases contained within the water to be frozen may be trapped in a solidified ice cube during the freezing process. For example, impurities and gases may be trapped near the center or the bottom surface of the ice cube, due to their inability to escape and as a result of the freezing liquid to solid phase change of the ice cube surfaces. Separate from or in addition to the trapped impurities and gases, a dull or cloudy finish may form on the exterior surfaces of an ice cube (e.g., during rapid freezing of the ice cube). Generally, a cloudy or opaque ice cube is the resulting product of typical ice making appliances.

**[0004]** Although typical ice cubes may be suitable for a number uses, such as temporary cold storage and rapid cooling of liquids in a wide range of sizes, they may present several disadvantages. As an example, impurities and gases trapped within an ice cube may impart undesirable flavors into a beverage being cooled (i.e., a beverage in which the ice cube is placed) as the ice cube melts. Such impurities and gases may also cause an ice cube to melt unevenly or faster (e.g., by increasing the exposed surface area of the ice cube). Evenly-distributed or slow melting of ice may be especially desirable in certain liquors or cocktails. Additionally or alternatively, it has been found that substantially clear ice cubes (e.g., free of any visible impurities or dull finish) may provide a unique or upscale impression for the user.

**[0005]** Accordingly, further improvements in the field of ice making would be desirable. In particular, it may be desirable to provide an appliance or methods for rapidly and reliably producing substantially clear ice.

### BRIEF DESCRIPTION OF THE INVENTION

**[0006]** Aspects and advantages of the invention will be set forth in part in the following description, or may be obvious from the description, or may be learned through practice of the invention.

**[0007]** In one aspect of the present disclosure, an ice making assembly is provided including a chilled chamber, a central hub rotatably mounted within the chilled chamber, a mold assembly mechanically coupled to the central hub, the mold assembly defining a mold cavity configured for receiving water, and a drive mechanism operably coupled to the central hub for selectively rotating the central hub at a rotation speed. A controller is operably coupled to the drive mechanism and is configured for accelerating the central hub until the rotation speed reaches a target speed and periodically reducing the rotation speed of the central hub to a reduced speed before accelerating back to the target speed.

**[0008]** In another aspect of the present disclosure, a method of operating an ice making assembly is provided. The ice making assembly includes a central hub rotatably mounted within a chilled chamber and a mold assembly mechanically coupled to the central hub and defining a mold cavity configured for receiving water. The method includes accelerating the central hub until a rotation speed reaches a target speed and periodically reducing the rotation speed of the central hub to a reduced speed before accelerating back to the target speed.

**[0009]** These and other features, aspects and advantages of the present invention will become better understood with reference to the following description and appended claims. The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0010]** 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 side schematic view of an ice making assembly according to exemplary embodiments of the present disclosure.

FIG. 2 provides a schematic view of a mold assembly for use with the exemplary ice making assembly of FIG. 1 according to exemplary embodiments of the present disclosure.

FIG. 3 provides a perspective view of an ice making assembly according to another exemplary embodiment of the present disclosure.

FIG. 4 provides a perspective view of a mold assembly for use with the exemplary ice making assembly of FIG. 3 according to exemplary embodiments of

the present disclosure.

FIG. 5 provides a perspective view of an ice mold of the exemplary mold assembly of FIG. 4 according to exemplary embodiments of the present disclosure.

FIG. 6 illustrates a method of operating an ice making assembly according to an exemplary embodiment of the present subject matter.

**[0011]** 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

**[0012]** 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.

**[0013]** As used herein, 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"). Approximating language, as used herein throughout the specification and claims, is 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 "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. For example, the approximating language may refer to being within a 10 percent margin.

**[0014]** Turning now to the figures, FIG. 1 provides a side schematic view of an ice making assembly 100 according to exemplary embodiments of the present disclosure. FIG. 2 provides schematic view of certain components of ice making assembly 100 according to exemplary embodiments of the present disclosure. Generally, ice making assembly 100 includes a cabinet 102 (e.g., an insulated housing) and defines a mutually orthogonal vertical direction V, lateral direction L, and transverse direction (not shown). The lateral direction and transverse direction may be generally understood to be horizontal directions H.

**[0015]** As shown, cabinet 102 defines one or more chilled chambers, such as a chilled chamber 104. In certain embodiments, such as those illustrated by FIG. 1, ice making assembly 100 is understood to be formed as, or as part of, a stand-alone ice making appliance, such as a countertop icemaker. It is recognized, however, that additional or alternative embodiments may be provided within the context of other ice making or refrigeration appliances. For instance, the benefits of the present disclosure may apply to any type or style of a refrigerator appliance that includes a freezer chamber (e.g., a top mount refrigerator appliance, a bottom mount refrigerator appliance, a side-by-side style refrigerator appliance, etc.). Consequently, the description set forth herein is for illustrative purposes only and is not intended to be limiting in any aspect to any appliance configuration.

**[0016]** As shown schematically in FIG. 1, ice making assembly 100 may further include sealed refrigeration system 110 for executing a vapor compression cycle for cooling water within ice making assembly 100 (e.g., within chilled chamber 104). Sealed refrigeration system 110 includes a compressor 112, a condenser 114, an expansion device 116, and an evaporator 118 connected in fluid series and charged with a refrigerant. As will be understood by those skilled in the art, sealed refrigeration system 110 may include additional components (e.g., one or more directional flow valves or an additional evaporator, compressor, expansion device, or condenser). Moreover, at least one component (e.g., evaporator 118) is provided in thermal communication (e.g., conductive thermal communication) with an ice mold or chilled chamber 104 to cool the ice mold, such as during ice making operations. Optionally, evaporator 118 is mounted within chilled chamber 104, as generally illustrated in FIG. 1.

**[0017]** Within sealed refrigeration system 110, gaseous refrigerant flows into compressor 112, 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 114. Within condenser 114, heat exchange with ambient air takes place so as to cool the refrigerant and cause the refrigerant to condense to a liquid state.

**[0018]** Expansion device 116 (e.g., a mechanical valve, capillary tube, electronic expansion valve, or other restriction device) receives liquid refrigerant from condenser 114. From expansion device 116, the liquid refrigerant enters evaporator 118. Upon exiting expansion device 116 and entering evaporator 118, the liquid refrigerant drops in pressure and vaporizes. Due to the pressure drop and phase change of the refrigerant, evaporator 118 is cool relative to chilled chamber 104. As such, cooled water and ice or air is produced and refrigerates ice making assembly 100 or chilled chamber 104. Thus, evaporator 118 is a heat exchanger which transfers heat from water or air in thermal communication with evaporator 118 to refrigerant flowing through evaporator 118.

**[0019]** A user interface panel 120 may be provided for controlling the mode of operation. For example, user in-

terface panel 120 may include a plurality of user inputs 122, such as a touchscreen or button interface, for selecting a desired mode of operation. According to an exemplary embodiment, a display 124 indicates selected features, a countdown timer, and/or other items of interest to appliance users. User interface panel 120, input selectors 122, and display 124 collectively form a user interface input or control panel for operator selection of appliance cycles and features, as well as to receive useful information regarding appliance operation.

**[0020]** Operation of ice making assembly 100 can be regulated by a controller 126 that is operatively coupled to user interface panel 120 or various other components, as will be described below. User interface panel 120 provides selections for user manipulation of the operation of ice making assembly 100 such as (e.g., selections regarding chamber temperature, ice making speed, or other various options). In response to user manipulation of user interface panel 120, or one or more sensor signals, controller 126 may operate various components of the ice making assembly 100.

**[0021]** Controller 126 may include a memory (e.g., non-transitive memory) and one or more microprocessors, CPUs or the like, such as general or special purpose microprocessors operable to execute programming instructions or micro-control code associated with operation of ice making assembly 100. The memory may represent random access memory such as DRAM, or read only memory such as ROM or FLASH. In one embodiment, the processor executes programming instructions stored in memory. The memory may be a separate component from the processor or may be included onboard within the processor. Alternatively, controller 126 may be constructed without using a microprocessor (e.g., using a combination of discrete analog or digital logic circuitry; such as switches, amplifiers, integrators, comparators, flip-flops, AND gates, and the like; to perform control functionality instead of relying upon software).

**[0022]** Controller 126 may be positioned in a variety of locations throughout ice making assembly 100. In optional embodiments, controller 126 is located within the user interface panel 120. In other embodiments, the controller 126 may be positioned at any suitable location within ice making assembly 100, such as for example within cabinet 102. Input/output ("I/O") signals may be routed between controller 126 and various operational components of ice making assembly 100. For example, user interface panel 120 may be in communication with controller 126 via one or more signal lines or shared communication busses.

**[0023]** As illustrated, controller 126 may be in communication with the various components of ice making assembly 100 and may control operation of the various components. For example, various valves, switches, etc. may be actuatable based on commands from the controller 126. As discussed, user interface panel 120 may additionally be in communication with the controller 126. Thus, the various operations may occur based on user input or automatically through controller 126 instruction.

**[0024]** In some embodiments, ice making assembly 100 includes a door 128 that is rotatably attached to cabinet 102 (e.g., at a top portion thereof). As would be understood, door 128 may selectively cover an opening defined by cabinet 102 to provide selective access to chilled chamber 104. For instance, door 128 may rotate on cabinet 102 between an open position (FIG. 1) permitting access to chilled chamber 104 and a closed position (not shown) restricting access to chilled chamber 104. Door 128 may be insulated to help maintain chilled chamber 104 at suitably low temperatures.

**[0025]** Referring still to FIGS. 1 and 2, ice making assembly 100 will be described in more detail according to an exemplary embodiment of the present subject matter. In describing ice making assembly 100, reference may also be made herein to FIGS. 3 through 5, which provide an exemplary embodiment or test set up of ice making assembly 100. Notably, due to the similarity between ice making assembly 100 from FIGS. 1-2 and FIGS. 3-5, like reference numerals may be used to refer to the same or similar features. In addition, it should be appreciated that the embodiments shown are only exemplary and not intended to limit the scope of the present subject matter in any manner.

**[0026]** As shown, ice making assembly 100 includes a central hub 140 that is rotatably mounted within chilled chamber 104. More specifically, as illustrated, central hub 140 may be rotatable about a central axis 142 that extends substantially along the vertical direction V. Ice making assembly 100 may further include a drive mechanism, such as a drive motor 144 that is operably coupled to central hub 140 for selectively rotating central hub 140 at a desired rotation speed. Specifically, as illustrated, motor 144 may be positioned below central hub 140 and may be operably or mechanically coupled to central hub 140 via a drive shaft 146. According to exemplary embodiments, controller 126 is in operative communication with drive motor 144 for regulating the rotation of central hub 140 within ice making assembly 100.

**[0027]** As used herein, "motor" may refer to any suitable drive motor and/or transmission assembly for driving central hub 140. For example, drive motor 144 may be a brushless DC electric motor, a stepper motor, or any other suitable type or configuration of motor. For example, drive motor 144 may be an AC motor, an induction motor, a permanent magnet synchronous motor, or any other suitable type of AC motor. In addition, drive motor 144 may include any suitable motor or transmission sub-assemblies, clutch mechanisms, or other components.

**[0028]** Ice making assembly 100 further includes a mold assembly 150 that is mechanically coupled to central hub 140. Specifically, according to the illustrated embodiment, mold assembly 150 includes one or more yokes 152 that are mounted to central hub 140 and have a pin or an axle 154 attached at their distal end. As shown, mold assembly 150 further includes one or more ice molds 156 that are rotatably coupled to axles 154 such that they may rotate during operation of ice making ap-

pliance 100. More specifically, as central hub 140 rotates, centrifugal force may cause ice molds 156 to rotate from a vertical orientation (e.g., as shown in solid lines in FIG. 1 or in FIG. 3) to a horizontal orientation (e.g., as shown in dotted lines in FIG. 1 or in FIG. 4).

**[0029]** According to the illustrated embodiment, central hub 140 is a cylindrical structure defining an inner surface 158 to which the plurality of yokes 152 is attached. Specifically, central hub 140 contains or surrounds mold assemblies 150. However, it should be appreciated that according to alternative embodiments, central hub 140 may be any other suitable structure that restrains ice molds 156 during rotation of central hub 140. For example, according to an alternative embodiment, central hub 140 may be a vertical shaft or an extension of drive shaft 146 that is surrounded by ice molds 156 and corresponding support arms. According to the illustrated embodiment, mold assembly 150 includes three yokes 152 that are spaced apart along a circumferential direction within central hub 140. In addition, each yoke is designed to rotatably support a single ice mold 156. However, it should be appreciated that any other suitable number and configuration of yokes 152 and ice molds 156 may be used according to alternative embodiments.

**[0030]** Referring now specifically to FIG. 2, ice mold 156 will be described in more detail according to an exemplary embodiment. As illustrated, ice mold 156 includes a cylindrical sidewall 160 and a bottom wall 162 that are joined to define a mold cavity 164. Mold cavity 164 is generally configured for receiving and containing water (e.g. as indicated by reference numeral 166 in FIG. 2). An opening 168 to mold cavity 164 is defined by cylindrical sidewall 160 opposite of bottom wall 162. As shown, ice mold 156 includes a top cap 170 that is positioned over opening 168 of ice mold 156 for selectively closing mold cavity 164. Top 170 may be secured to cylindrical sidewall 160 in any suitable manner. For example, according to the illustrated embodiment, top cap 170 and cylindrical sidewall 160 define a threaded connection 172. According to alternative embodiments, top cap 170 may be secured in any other suitable manner, such as being press-fit, snap fit, or secured by a mechanical fastener. It should be appreciated that top cap 170 may further define one or more vents (not shown) to permit degassing during ice formation.

**[0031]** As also illustrated in FIG. 2, ice mold 156 may define or include features to facilitate directional freezing of water 166 within mold cavity 164. For example, according to the illustrated embodiment, cylindrical sidewall 160 and top cap 170 are covered in an insulating material 174. In addition, ice mold 156 may include one or more heat sinks 176 defined by or mounted to bottom wall 162 of ice mold 156 to facilitate improved heat extraction from the bottom of ice mold 156. According to alternative embodiments, heat sinks 176 may be further defined on a bottom portion or lower end of cylindrical sidewall 160.

**[0032]** In general, ice mold 156 and its components may be formed from any suitable material or materials

to achieve the desired thermal properties of ice mold 156 for improving the ice formation process. For example, ice mold 156 is generally formed from a thermally conductive material (e.g., metal, such as copper, aluminum, or stainless steel, including alloys thereof) while insulating material 174 is generally formed from a thermally insulating material (e.g., insulating polymer, such as a synthetic silicone configured for use within subfreezing temperatures without significant deterioration). According to alternative embodiments, insulating material 174 may be formed using closed-cell extruded polystyrene foam (XPS) or any other suitable material.

**[0033]** Notably, one or more portions of sealed refrigeration system 110 may be in thermal communication with mold assembly 150. In particular, evaporator 118 may be placed on or in contact (e.g., conductive contact) with a portion of mold assembly 150. Alternatively, evaporator 118 may be used to extract heat from chilled chamber 104. In this manner, evaporator 118 may selectively draw heat from mold cavity 164, as will be further described below. During operation, a water supply 180 (FIG. 2) may be positioned above mold assemblies 150 and may selectively dispense a flow of water 166 into mold cavities 164. Generally, water supply 180 includes at least one nozzle 182 for selectively filling mold cavity 164. In embodiments where multiple discrete mold cavities 164 are defined by mold assembly 150, water supply 180 may include a plurality of nozzles 182 or fluid pumps vertically aligned with the plurality mold cavities 164. For instance, each mold cavity 164 may be vertically aligned with a discrete nozzle 182.

**[0034]** As shown, controller 126 may be in communication (e.g., electrical communication) with one or more portions of ice making assembly 100. In some embodiments, controller 126 is in communication with the water supply 180, compressor 112, flow regulating valves or nozzles 182, drive motor 144, user interface panel 120, etc. Controller 126 may be configured to initiate discrete ice making operations, as will be described in more detail below. For example, controller 126 may initiate or direct water supply 180 to provide a flow of water 166 through nozzle 182 and into mold cavity 164 (e.g., through mold opening 168). Controller 126 may further direct sealed refrigeration system 110 (e.g., at compressor 112) (FIG. 1) to motivate refrigerant through evaporator 118 and draw heat from within mold cavity 164.

**[0035]** Notably, according to the exemplary embodiment described above, heat sinks 176 and insulating material 174 operate together to encourage the cooling of water 166 within mold cavity 164 from the bottom-up (e.g., starting at a bottom wall 162). In this manner, a portion of the water 166 may freeze in progressive layers from bottom wall 162 to opening 168. In addition, drive shaft 146 may rotate during operation, thus causing central hub 140 to rotate and ice mold 156 to rotate from a vertical orientation to a horizontal orientation. Notably, as described below, the centrifugal force exerted on water 166 within ice mold 156 may facilitate an improved

freezing process that results in fewer impurities in cloudiness within the formed ice billet.

**[0036]** Now that the construction of ice making assembly 100 has been described according to exemplary embodiments, an exemplary method 200 of operating an ice making assembly will be described. Although the discussion below refers to the exemplary method 200 of operating ice making assembly 100, one skilled in the art will appreciate that the exemplary method 200 is applicable to the operation of a variety of other ice making assemblies and methods of ice formation.

**[0037]** Referring now to FIG. 6, method 200 includes, at step 210, supplying water into a mold cavity of a mold assembly, wherein the mold assembly is pivotally mounted to a central hub within a chilled chamber. In this regard, continuing example from above, water supply 180 may open nozzle 182 supply a flow of water 166 into mold cavity 164 of ice mold 156. Sealed system 110 may operate to lower the temperature of chilled chamber 104 to a suitable temperature ice for freezing water 166 into an ice billet (not shown). For example, according to an exemplary embodiment, the temperature within chilled chamber 104 may be dropped to below freezing, about 0°F, or to any other suitable temperature.

**[0038]** Notably, while water 166 is freezing, controller 126 may operate drive motor 144 to rotate central hub 140. More specifically, drive motor 144 may accelerate central hub 140 until the rotation speed reaches a target speed and may periodically reduce the rotation speed of central hub 142 or reduce speed before accelerating back to the target speed or another suitably elevated speed. As explained in more detail below, this method of accelerating and periodically decelerating central hub 140 results in the formation of a clear ice billet with minimal impurities.

**[0039]** More specifically, step 220 includes accelerating the central hub until a rotation speed of the central hub reaches a target speed. For example, the target speed may be any suitable rotational speed that creates centrifugal force on water 166 thereby increasing the pressure of water 166 proximate bottom wall 162. For example, according to an exemplary embodiment, the target speed may be greater than about 200 revolutions per minute (RPM), greater than about 400 RPM, greater than about 600 RPM, or about 800 RPM. In addition, or alternatively, the target speed may be less than about 3000 RPM, less than about 2500 RPM, less than about 2000 RPM, less than about 1000 RPM, less than about 600 RPM, or any other suitable speed.

**[0040]** Step 230 includes periodically reducing the rotation speed of the central hub to a reduced speed before accelerating back to the target speed. More specifically, according to an exemplary embodiment, this periodic speed reduction may include (a) accelerating the central hub until the rotation speed reaches the target speed; (b) maintaining the rotation speed of the central hub at the target speed for a spin time; (c) reducing the rotation speed of the central hub to the reduced speed for a dwell

time; and (d) repeating steps (a)-(c) until the water in the mold cavity forms a billet of ice. Although step (c) recites reducing the rotation speed to a reduced speed for a dwell time, it should be appreciated that according to exemplary embodiments, this may involve two steps of decelerating and maintaining the rotation speed for the dwell time.

**[0041]** Notably, the reduced speed is generally selected as a speed at or below which gases or impurities within water 166 may evacuate, outgas, effervesce, or otherwise clear the freezing portion of water 166, as will be described in more detail below. According to exemplary embodiments, the reduced speed may be zero, such that drive motor 144 is completely turned off during the dwell time. According to alternative embodiments, the reduced speed may be zero, greater than zero, etc. For example, the reduced speed may be between about 0% and 70%, between about 5% and 50%, or about 20%, of the target speed. According to exemplary embodiments, the reduced speed may be less than about 30%, less than about 20%, less than about 10%, less than about 5%, less than about 1%, less than about 0.1%, or less, than the target speed. Other reduced speeds are possible and within scope of the present subject matter.

**[0042]** According to exemplary embodiments, the spin time at which central hub 140 is rotated at the target speed may be any suitable duration. For example, spin time may be between about 1 and 20 minutes, between about 2 and 7 minutes, between about 3 and 5 minutes, or about 4 minutes. Similarly, the dwell time may be any suitable time duration that facilitates degassing or impurity removal from water 166 during a freezing process. For example, the dwell time may be between about 1 second and 5 minutes, between about 3 seconds and 45 seconds, between about 5 seconds and 30 seconds, or any other suitable time duration.

**[0043]** It should be appreciated that ice making assembly 100 may further include one or more vibration devices 190, e.g., for introducing vibrations into mold assembly 150 during any portion of the spin, time, the dwell time, or both in order to further facilitate the evacuation/outgassing/effervescence of impurities from water 166. Furthermore, mold assembly 150 may include one or more heating elements 192 for selectively heating the ice mold 156 or water 166 stored therein. For example, a heating element may be provided for controlled heating of the top surface of water 166 in the ice mold 156 to maintain liquid water and ensure an outgassing escape path throughout the entire ice making cycle.

**[0044]** According to exemplary embodiments, controller 126 may operate drive motor 144 such that a spin ratio of the spin time over a total time falls within a suitable range. In this regard, the total time may be equivalent to the spin time plus the dwell time, e.g., or a total cycle time. According to exemplary embodiments, the suitable range for the spin ratio may be between about 0.5 and 0.99, between about 0.6 and 0.95, between about 0.7 and 0.85, or about 0.8. It should be appreciated that the

parameters such as the target speed in the speed reduction cycle described herein are only exemplary and not intended to limit the scope of the present subject matter. For example, although central hub 140 is described as being rotated back to target speed after every deceleration, it should be appreciated that according to alternative embodiments, the elevated speed or target speed may vary while remaining within scope of the present subject matter.

**[0045]** FIG. 6 depicts steps performed in a particular order for purposes of illustration and discussion. Those of ordinary skill in the art, using the disclosures provided herein, will understand that the steps of any of the methods discussed herein can be adapted, rearranged, expanded, omitted, or modified in various ways without deviating from the scope of the present disclosure. Moreover, although aspects of method 200 are explained using ice making assembly 100 as an example, it should be appreciated that these methods may be applied to the operation of any ice making assembly or appliance having any other suitable configuration.

**[0046]** Notably, ice making assembly 100 and method 200 described above provide an improved ice making assembly and process for achieving ice billets with improved purity and quality. In this regard, high speed rotation of an ice mold during freezing provides several significant benefits in producing clear ice. Specifically, as described above, a plurality of stainless steel ice molds may be fastened to a rotation mechanism, such a central hub, via a swinging yoke and support system. Each ice mold may include a heat sink affixed to its underside and insulation surrounding the walls and top. The heat sink and insulation force primary heat transfer through the bottom face of the ice mold, allowing directional freezing within the water from the bottom upward (from the outside radius toward the center of rotation). This directional freezing allows the freeze front to push dissolved air and other impurities into remaining liquid water instead of trapping them within a freezing ice shell.

**[0047]** For example, according to an exemplary ice making cycle, the ice mold s may be filled with filtered water to a controlled depth, while the entire ice mold sits within a thermal chamber set to a suitably low temperature, such as 0°F. The basket is then spun to the desired spin speed, such as a maximal spin speed of 800 RPM. This provides large centrifugal acceleration within the central hub and the ice molds of water (200 g at the basket radius); as a result, the weight of the water increases by a proportional amount, and the pressure vs. depth (due to the increased weight) increases significantly as well (up at 3x times atmospheric pressure at the bottom of the cup). The total height of the water column within the central hub may be significant, since the pressure is directly related to the water depth.

**[0048]** Further, the solubility of air within water may be directly proportional to the water pressure; thus, the solubility may increase as a direct response to the basket rotation. At typical atmospheric pressure and normal sol-

ubility conditions, the progressing freeze front may push dissolved air into the remaining liquid water; as this occurs, the solute density increases, and the solution soon may become oversaturated, forcing air to come out of solution and clouding the ice. However, the increased solubility may allow more freezing to occur before the solution becomes oversaturated with air.

**[0049]** Additionally, the basket speed may be routinely lowered to zero or a reduced speed for a moment every few minutes; these static or slow periods may allow the pressure and solubility of the solution to return to normal, atmospheric values, which causes the solution to immediately become oversaturated due to the increased solute density. As a result, the solution may release excess dissolved air, similar to the release of carbonation after opening a soda bottle. In this manner, the speed of the basket can be pulsed every few minutes to regularly induce a forced effervescence to rid the solution of excess air and to continue freezing clear ice. Vibrating the mold assembly during any dwell speed or time may further release dissolved gases from the water, similar to shaking and open soda container. Controlled heating of the top surface of the water in the mold assembly may also be introduced to maintain liquid water to ensure an out-gassing escape path throughout the entire ice making cycle. The high rotational speeds (in addition to the fins of the cavity heat sinks) may allow for a very large convection coefficient of cooling, meaning that ice can form very quickly during spinning periods. In addition, the large centrifugal effects may increase the buoyancy forces felt on a typical air bubble within the water, most likely forcing any bubbles to be released to the surface much more quickly than under ordinary conditions. Lastly, the small yet continuous agitating vibrations of the basket during spin states may play a beneficial role in helping release air bubbles which may be adhered to the walls of the ice mold.

**[0050]** 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. An ice making assembly comprising:
  - a chilled chamber;
  - a central hub rotatably mounted within the

- chilled chamber;  
a mold assembly mechanically coupled to the central hub, the mold assembly defining a mold cavity configured for receiving water;  
a drive mechanism operably coupled to the central hub for selectively rotating the central hub at a rotation speed; and  
a controller operably coupled to the drive mechanism, the controller being configured for:
- accelerating the central hub until the rotation speed reaches a target speed; and  
periodically reducing the rotation speed of the central hub to a reduced speed before accelerating back to the target speed.
2. The ice making assembly of claim 1, wherein the reduced speed is less than 20% of the target speed.
  3. The ice making assembly of claim 1, wherein the target speed is between about 600 and 2000 revolutions per minute.
  4. The ice making assembly of claim 1, wherein the reduced speed is between about 0% and 50% of the target speed.
  5. The ice making assembly of claim 1, wherein periodically reducing the rotation speed of the central hub comprises:
    - (a) accelerating the central hub until the rotation speed reaches the target speed;
    - (b) maintaining the rotation speed of the central hub at the target speed for a spin time;
    - (c) reducing the rotation speed of the central hub to the reduced speed for a dwell time; and
    - (d) repeating steps (a)-(c) until the water in the mold cavity forms a billet of ice.
  6. The ice making assembly of claim 5, wherein a spin ratio of the spin time over a total time equal to the spin time plus the dwell time is between about 0.8 and 0.99.
  7. The ice making assembly of claim 6, wherein the spin ratio is between about 0.9 and 0.99.
  8. The ice making assembly of claim 5, wherein the spin time is between about 2 and 15 minutes.
  9. The ice making assembly of claim 5, wherein the dwell time is between about 5 seconds and 5 minutes.
  10. The ice making assembly of claim 1, wherein the mold assembly comprises:
    - a yoke;
    - an ice mold defining the mold cavity and an opening to the mold cavity, the ice mold being pivotally mounted to the yoke such that the opening faces upward during a filling process and pivots toward a lateral direction when the central hub is rotated.
  11. The ice making assembly of claim 10, wherein the mold assembly comprises:
    - a top cap positioned over the opening in the ice mold, wherein the top cap is insulated.
  12. The ice making assembly of claim 10, wherein the mold assembly comprises:
    - a vibration device operably coupled to the ice mold for selectively vibrating the ice mold.
  13. The ice making assembly of claim 10, wherein the mold assembly comprises:
    - a heating element in thermal communication with the ice mold for selectively heating the ice mold.
  14. The ice making assembly of claim 10, wherein the ice mold comprises a cylindrical sidewall, and wherein insulation surrounds the cylindrical sidewall.
  15. The ice making assembly of claim 10, wherein the ice mold comprises:
    - one or more heat sinks mounted to a bottom wall of the ice mold to facilitate directional freezing.
  16. The ice making assembly of claim 10, wherein the ice mold is constructed from aluminum.
  17. The ice making assembly of claim 1, wherein the central hub is cylindrical and defines an inner surface, the mold assembly being mounted on the inner surface.
  18. The ice making assembly of claim 1, wherein the drive mechanism comprises an electric motor mounted below the central hub.
  19. A method of operating an ice making assembly, the ice making assembly comprises a central hub rotatably mounted within a chilled chamber and a mold assembly mechanically coupled to the central hub and defining a mold cavity configured for receiving water, the method comprising:
    - accelerating the central hub until a rotation speed reaches a target speed; and
    - periodically reducing the rotation speed of the central hub to a reduced speed before accelerating back to the target speed.
  20. The method of claim 19, wherein periodically reduc-

ing the rotation speed of the central hub comprises:

- (a) accelerating the central hub until the rotation speed reaches the target speed;
- (b) maintaining the rotation speed of the central hub at the target speed for a spin time; 5
- (c) reducing the rotation speed of the central hub to the reduced speed for a dwell time; and
- (d) repeating steps (a)-(c) until water in the mold cavity forms a billet of ice. 10

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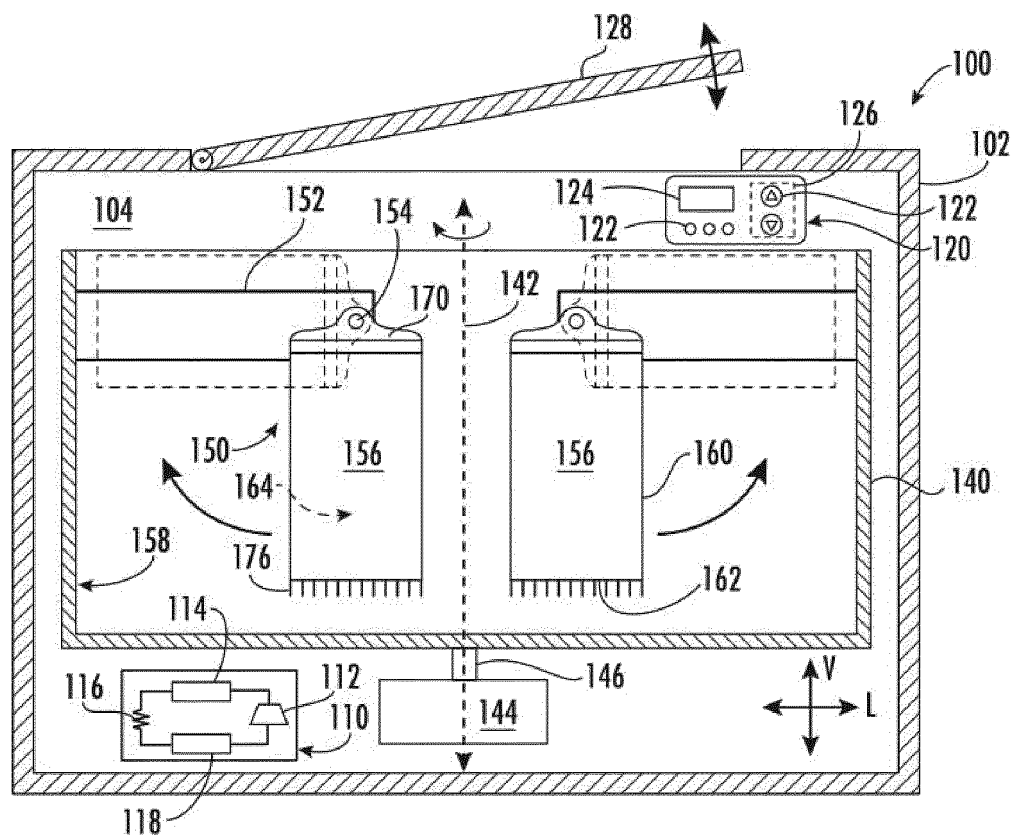


FIG.1

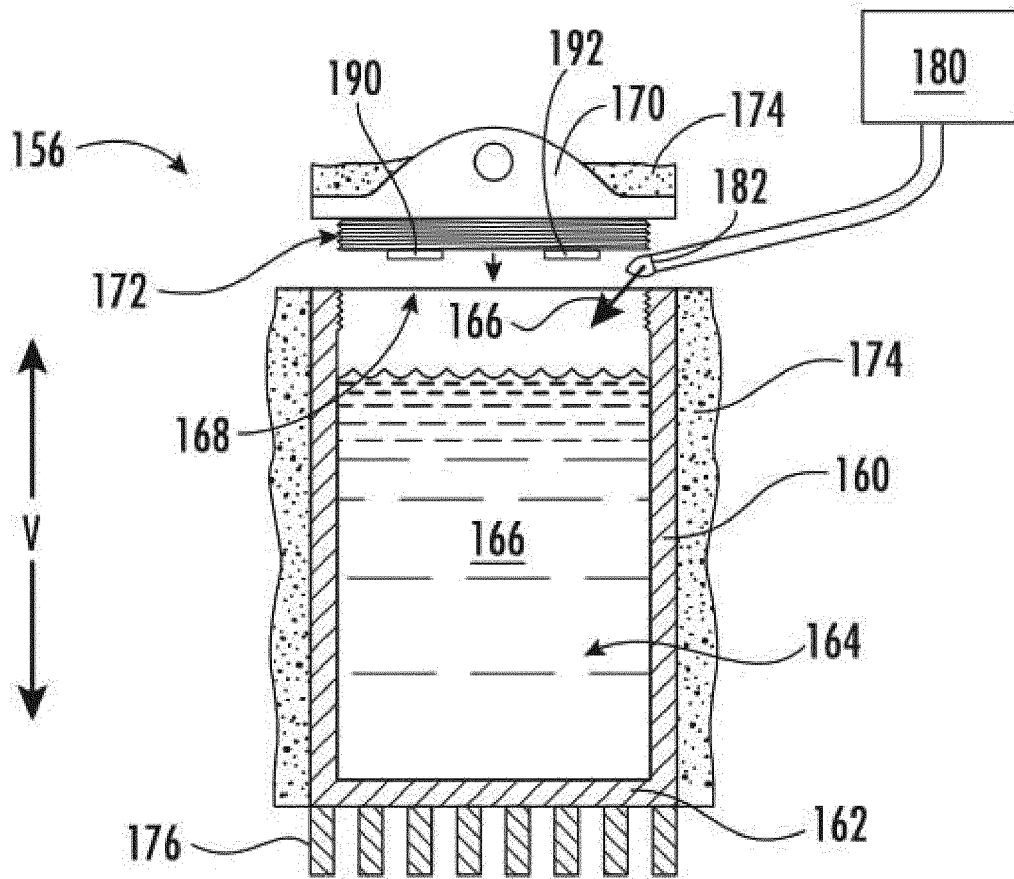


FIG. 2

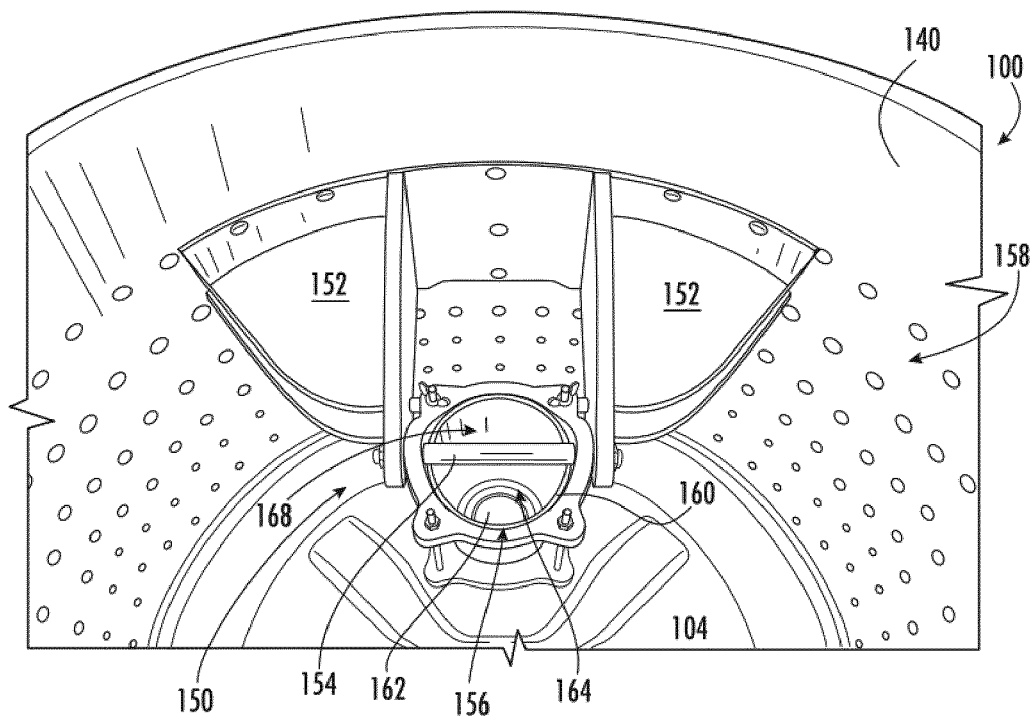


FIG. 3

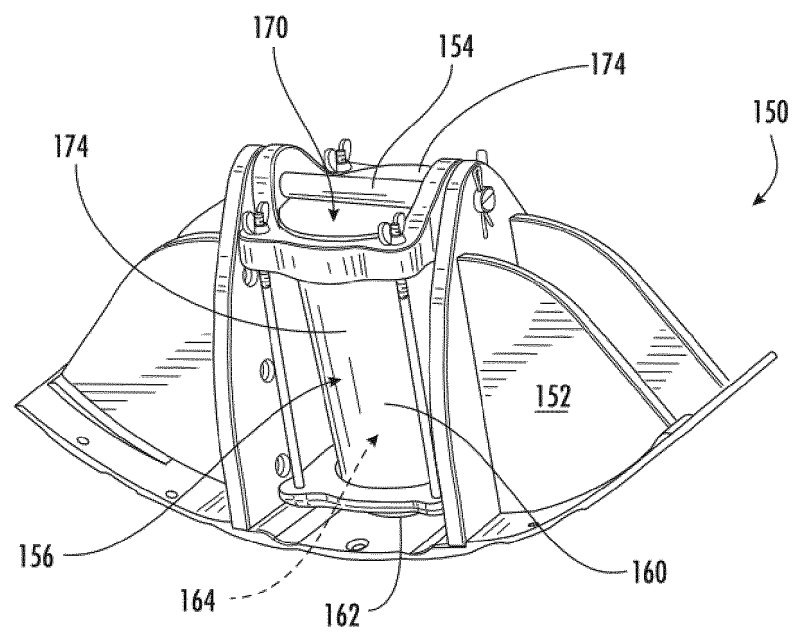


FIG. 4

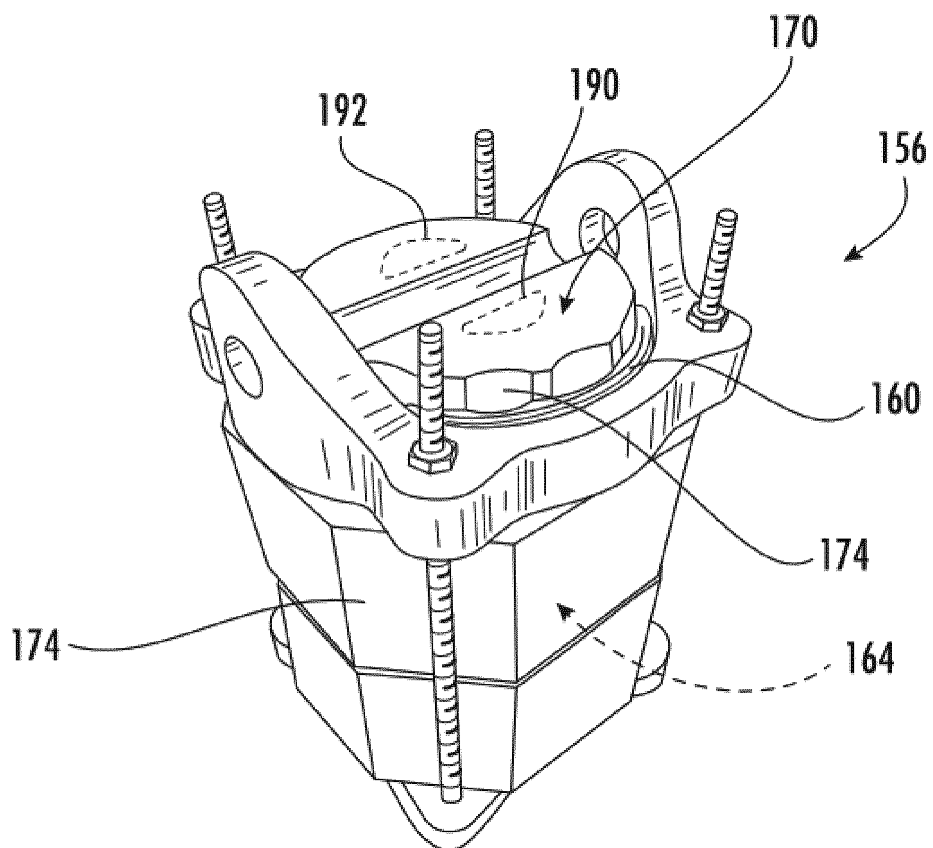


FIG. 5

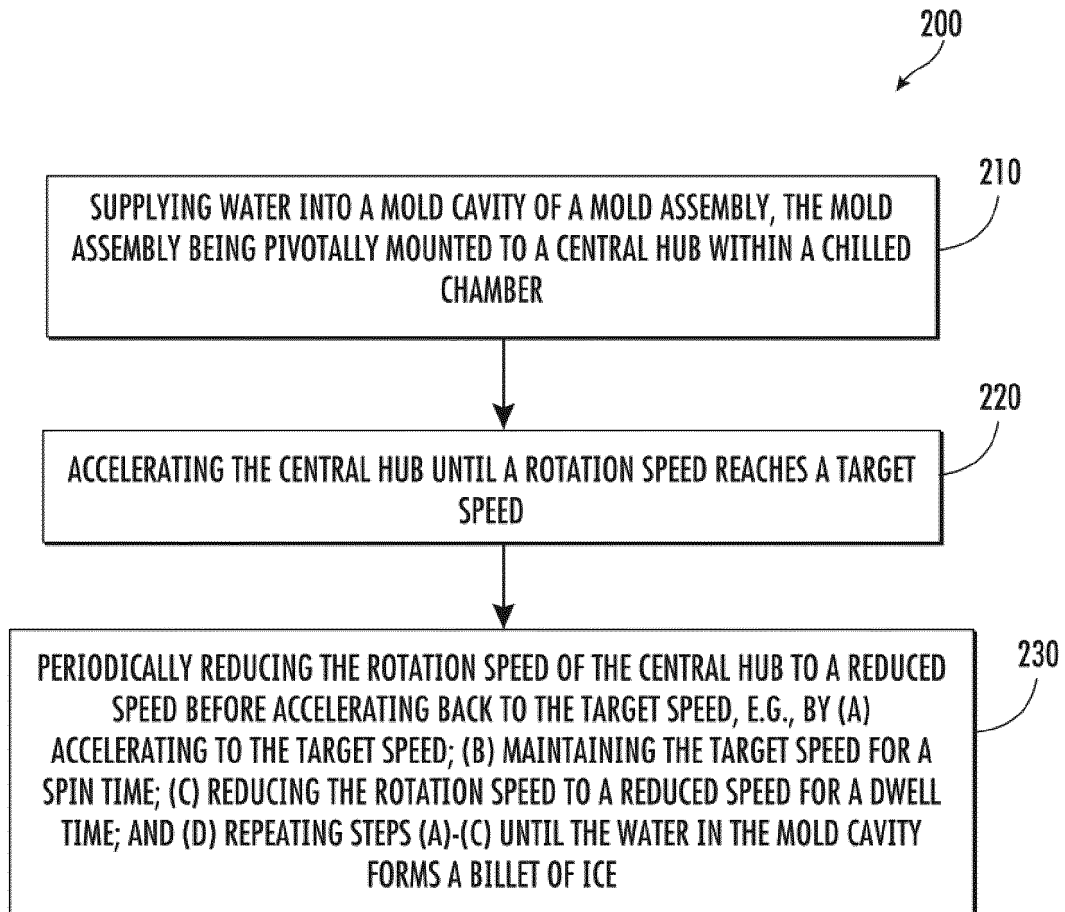


FIG.6

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2021/077331

| <b>A. CLASSIFICATION OF SUBJECT MATTER</b><br>F25C 1/18(2006.01)i<br>According to International Patent Classification (IPC) or to both national classification and IPC                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                        |                                                                                    |                       |   |                                                                                                                  |      |   |                                                                        |      |   |                                                                                                                        |      |   |                                                                                        |      |  |  |
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| <b>B. FIELDS SEARCHED</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                        |                                                                                    |                       |   |                                                                                                                  |      |   |                                                                        |      |   |                                                                                                                        |      |   |                                                                                        |      |  |  |
| Minimum documentation searched (classification system followed by classification symbols)<br>F25C1 F25C5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                        |                                                                                    |                       |   |                                                                                                                  |      |   |                                                                        |      |   |                                                                                                                        |      |   |                                                                                        |      |  |  |
| 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)<br>CNABS, CNTXT, CNKI, DWPI: 模 转 离 心 透 明 纯 净 速 度 mould mold rotat+ centrifugal+ transpar+ pur+ speed                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                        |                                                                                    |                       |   |                                                                                                                  |      |   |                                                                        |      |   |                                                                                                                        |      |   |                                                                                        |      |  |  |
| <b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                        |                                                                                    |                       |   |                                                                                                                  |      |   |                                                                        |      |   |                                                                                                                        |      |   |                                                                                        |      |  |  |
| <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>A</td> <td>JP 2008008526 A (SHARP K. K.) 17 January 2008 (2008-01-17) description, paragraphs [0064]-[0082] and figures 4-6</td> <td>1-20</td> </tr> <tr> <td>A</td> <td>US 2986013 A (PHILCO., CORP.) 30 May 1961 (1961-05-30) entire document</td> <td>1-20</td> </tr> <tr> <td>A</td> <td>CN 210107827 U (GUANGZHOU HAIZHU DUOHAO REFRIGERATION EQUIPMENT FACTORY) 21 February 2020 (2020-02-21) entire document</td> <td>1-20</td> </tr> <tr> <td>A</td> <td>WO 2019025381 A1 (W SCHOONEN BEHEER B V) 07 February 2019 (2019-02-07) entire document</td> <td>1-20</td> </tr> </tbody> </table>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Category*                                                                                                              | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. | A | JP 2008008526 A (SHARP K. K.) 17 January 2008 (2008-01-17) description, paragraphs [0064]-[0082] and figures 4-6 | 1-20 | A | US 2986013 A (PHILCO., CORP.) 30 May 1961 (1961-05-30) entire document | 1-20 | A | CN 210107827 U (GUANGZHOU HAIZHU DUOHAO REFRIGERATION EQUIPMENT FACTORY) 21 February 2020 (2020-02-21) entire document | 1-20 | A | WO 2019025381 A1 (W SCHOONEN BEHEER B V) 07 February 2019 (2019-02-07) entire document | 1-20 |  |  |
| Category*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Citation of document, with indication, where appropriate, of the relevant passages                                     | Relevant to claim No.                                                              |                       |   |                                                                                                                  |      |   |                                                                        |      |   |                                                                                                                        |      |   |                                                                                        |      |  |  |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | JP 2008008526 A (SHARP K. K.) 17 January 2008 (2008-01-17) description, paragraphs [0064]-[0082] and figures 4-6       | 1-20                                                                               |                       |   |                                                                                                                  |      |   |                                                                        |      |   |                                                                                                                        |      |   |                                                                                        |      |  |  |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | US 2986013 A (PHILCO., CORP.) 30 May 1961 (1961-05-30) entire document                                                 | 1-20                                                                               |                       |   |                                                                                                                  |      |   |                                                                        |      |   |                                                                                                                        |      |   |                                                                                        |      |  |  |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | CN 210107827 U (GUANGZHOU HAIZHU DUOHAO REFRIGERATION EQUIPMENT FACTORY) 21 February 2020 (2020-02-21) entire document | 1-20                                                                               |                       |   |                                                                                                                  |      |   |                                                                        |      |   |                                                                                                                        |      |   |                                                                                        |      |  |  |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | WO 2019025381 A1 (W SCHOONEN BEHEER B V) 07 February 2019 (2019-02-07) entire document                                 | 1-20                                                                               |                       |   |                                                                                                                  |      |   |                                                                        |      |   |                                                                                                                        |      |   |                                                                                        |      |  |  |
| <input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                        |                                                                                    |                       |   |                                                                                                                  |      |   |                                                                        |      |   |                                                                                                                        |      |   |                                                                                        |      |  |  |
| <p>* Special categories of cited documents:</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier application or patent but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"&amp;" document member of the same patent family</p> |                                                                                                                        |                                                                                    |                       |   |                                                                                                                  |      |   |                                                                        |      |   |                                                                                                                        |      |   |                                                                                        |      |  |  |
| Date of the actual completion of the international search<br><b>22 April 2021</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Date of mailing of the international search report<br><b>28 April 2021</b>                                             |                                                                                    |                       |   |                                                                                                                  |      |   |                                                                        |      |   |                                                                                                                        |      |   |                                                                                        |      |  |  |
| Name and mailing address of the ISA/CN<br><b>China National Intellectual Property Administration (ISA/CN)</b><br><b>No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088</b><br><b>China</b><br>Facsimile No. (86-10)62019451                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Authorized officer<br><br><br><br><br>Telephone No.                                                                    |                                                                                    |                       |   |                                                                                                                  |      |   |                                                                        |      |   |                                                                                                                        |      |   |                                                                                        |      |  |  |

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**INTERNATIONAL SEARCH REPORT**  
**Information on patent family members**

International application No.

**PCT/CN2021/077331**

| Patent document<br>cited in search report |            |    | Publication date<br>(day/month/year) |  | Patent family member(s) |            |    | Publication date<br>(day/month/year) |  |
|-------------------------------------------|------------|----|--------------------------------------|--|-------------------------|------------|----|--------------------------------------|--|
| JP                                        | 2008008526 | A  | 17 January 2008                      |  | None                    |            |    |                                      |  |
| US                                        | 2986013    | A  | 30 May 1961                          |  | None                    |            |    |                                      |  |
| CN                                        | 210107827  | U  | 21 February 2020                     |  | None                    |            |    |                                      |  |
| WO                                        | 2019025381 | A1 | 07 February 2019                     |  | EP                      | 3438575    | A1 | 06 February 2019                     |  |
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