The present invention generally relates to a refrigerator including a third compartment arranged to maintain its temperature at, near or slightly below a freezing point of water so that aqueous articles stored therein may be cooled down to their freezing point but not completely frozen. More particularly, such a refrigerator generally includes a subzero compartment, an overzero compartment, and a near-zero compartment, where a control unit may be arranged to control temperatures of the compartments below zero degree, near (or at zero) degree, and over zero degree, respectively. Such a near-zero compartment is arranged to be in fluid communication with a cooling unit and/or subzero compartment to receive a subzero air stream therefrom, and defines an internal space which may preferably not be in direct fluid communication with either of the subzero and overzero compartments so that the control unit may control the temperature of the near-zero compartment at least substantially independently of the temperatures of the subzero and overzero compartments. Such a near-zero compartment of this invention may be incorporated to any household refrigerators, freezers, industrial refrigerators and/or freezers, household or commercial beverage dispensers, and the like. Such a near-zero compartment may also be manufactured as a separate console designated to chill beverages containers down to their freezing points. Furthermore, such a near-zero compartment may be provided as an add-on unit which may be retrofit into conventional refrigerators and/or freezers.
REFRIGERATORS WITH NEAR-ZERO COMPARTMENTS

[0001] The present application claims a benefit of an earlier filing date of a U.S. Provisional Application bearing a Serial Number U.S. Ser. No. 60/490,716, which was filed on Jul. 30, 2003, and which is entitled “Refrigerators with Near-Zero Compartments,” an entire portion of which is incorporated by reference herein.

FIELD OF THE INVENTION

[0002] The present invention generally relates to a refrigerator including a third compartment arranged to maintain its temperature at, near or slightly below a freezing point of water so that aqueous articles stored therein may be cooled down to their freezing point but not completely frozen. More particularly, such a refrigerator generally includes a subzero compartment, an overzero compartment, and a near-zero compartment, where a control unit may be arranged to control temperatures of the compartments below zero degree, near (or at zero) degree, and over zero degree, respectively. Such a near-zero compartment is arranged to be in fluid communication with a cooling unit and/or subzero compartment to receive a subzero air stream therefrom, and defines an internal space which may preferably not be in direct fluid communication with either of the subzero and overzero compartments so that the control unit may control the temperature of the near-zero compartment at least substantially independently of the temperatures of the subzero and overzero compartments. Such a near-zero compartment of this invention may be incorporated to any household refrigerators, freezers, industrial refrigerators and/or freezers, household or commercial beverage dispensers, and the like. Such a near-zero compartment may also be manufactured as a separate console designated to chill beverages containers down to their freezing points. Furthermore, such a near-zero compartment may be provided as an add-on unit which may be retrofit into conventional refrigerators and/or freezers.

BACKGROUND OF THE INVENTION

[0003] A conventional refrigerator includes two different compartments, i.e., a freezing compartment and a refrigerating compartment. The freezing compartment is typically maintained below zero degree (0° C.) to keep a variety of articles stored therein frozen. In some instances, the temperature of such a freezing compartment must be kept around -15° C. or below to prevent some articles such as, e.g., an ice cream, from melting. Therefore, the freezing compartment will now be referred to as a “subzero compartment” hereinafter. In contrary, the refrigerating compartment is maintained at or around a few degrees, e.g., from 2° C. to 5° C. to keep stored articles fresh or to prevent such articles from degrading, decaying or rotten. With the advent of packaging technologies, various beverages or drinks are now available in various containers. For example, carbonated drinks such as cola and cider are packed in metallic cans, plastic bottles, and/or glass bottles, and carbonated alcoholic drinks such as beers are also available in metallic cans or glass bottles. Non-carbonated drinks such as juices may be packed in cans, plastic bottles, glass bottles, paper packs, and the like.

[0004] In order to chill such beverages and drinks, an user has only two options, i.e., chill them in the overzero compartment or in the subzero compartment. When the user takes the first option, he or she may put the fluid containers in the overzero compartment and wait for a few hours for the containers to be cooled down to about 2° C. to 5° C. When the user prefers to cool the fluid containers below such temperatures or intends to enjoy slightly frozen drinks, he or she must place the fluid containers in the subzero compartment, while taking the risk of explosion of such containers due to expansion of fluids occurring during a phase change of such fluids.

[0005] Accordingly, there is a need for a refrigerator which provides a more safe and reliable way to cool beverage containers close to the freezing point thereof while preventing explosion of containers due to complete freezing of the fluid contents thereof.

SUMMARY OF THE INVENTION

[0006] The present invention generally relates to a refrigerator including a third compartment arranged to maintain its temperature at, near or slightly below a freezing point of water so that aqueous articles stored therein may be cooled down to their freezing point but not completely frozen. More particularly, such a refrigerator generally includes a subzero compartment, an overzero compartment, and a near-zero compartment, where a control unit may be arranged to control temperatures of the compartments below zero degree, near (or at zero) degree, and over zero degree, respectively. Such a near-zero compartment is arranged to be in fluid communication with a cooling unit and/or subzero compartment to receive a subzero air stream therefrom, and defines an internal space which may preferably not be in direct fluid communication with either of the subzero and overzero compartments so that the control unit may control the temperature of the near-zero compartment at least substantially independently of the temperatures of the subzero and overzero compartments.

[0007] In one aspect of the present invention, refrigerators may be provided to include various near-zero compartments. Such a refrigerator generally includes multiple compartments, a cooling unit, and a control unit, where such a cooling unit is arranged to provide a subzero air stream directly to at least one of such compartments and then indirectly to the rest of such compartments, while the control unit is arranged to control an amount(s) of the air stream(s) supplied to one or more of such compartments to control temperatures of such compartments. Such a refrigerator may include at least one subzero compartment, at least one overzero compartment, and at least one near-zero compartment.

[0008] In one exemplary embodiment, such a subzero compartment is in fluid communication with the cooling unit and has at least one first air inlet through which the air stream is supplied thereto from the cooling unit. The near-zero compartment is in fluid communication with the cooling unit and/or subzero compartment and has at least one second air inlet which is independent of (or operates independently of) the above first air inlet and through which the air stream is supplied thereto from the cooling unit and/or subzero compartment. The overzero compartment is in fluid communication with the cooling unit, near-zero compartment, and/or subzero compartment, and has at least one third air inlet which is independent of (or operates independently
of) the first and second air inlets and through which the air stream is supplied thereto from the cooling unit and/or subzero compartment. In such an embodiment, the subzero compartment may be arranged to receive the air stream from the cooling unit, while the overzero compartment may be arranged to receive the air stream from the cooling unit and/or subzero compartment and, optionally, from the near-zero compartment. The near-zero compartment may be arranged to receive the air stream from the cooling unit and/or subzero compartment. The exemplary refrigerator further includes multiple pathways which are arranged to be controlled by the control unit to close and open so as to stop and allow flow of the air stream therethrough, respectively, between at least two of the cooling unit and the compartments. The near-zero compartment may particularly be arranged to define an internal space therein which is not in (direct) fluid communication with either of the subzero and overzero compartments, except through the pathway(s) which may couple the near-zero compartment to the subzero compartment and/or overzero compartment.

In another exemplary embodiment, such a subzero compartment is arranged to receive the air stream from the cooling unit, the near-zero compartment is arranged to receive the air stream from the cooling unit and/or subzero compartment, while the overzero compartment is arranged to receive the air stream from the cooling unit, subzero compartment, and/or near-zero compartment. In addition, the refrigerator may include one or more air pathways which are arranged to be controlled by the control unit to respectively close and open to stop and allow flow of the air stream therethrough between at least two of the cooling unit and various compartments. More particularly, the near-zero compartment is arranged to define an internal space which is not in (direct) fluid communication with either of such a subzero and overzero compartments except through one or more of the air pathways arranged to couple the near-zero compartment to the subzero and/or overzero compartments.

In another exemplary embodiment, the subzero compartment receives the air stream from the cooling unit, while the near-zero compartment is arranged to receive the air stream from the cooling unit and subzero compartment. The near-zero compartment further includes one or more retainers which are arranged to occupy at least a substantial portion of one inner surface or plane of the near-zero compartment and to at least partly or partially retain one or more metal, glass, and/or plastic fluid containers therein. The overzero compartment is arranged to receive the air stream from the cooling unit, subzero compartment, and/or near-zero compartment. In another related exemplary embodiment, the subzero compartment is arranged to receive the air stream from the cooling unit, and has a first door arranged to provide an access to an interior thereof. The near-zero compartment is arranged to receive the air stream from the cooling unit and/or subzero compartment and includes a second door which is typically independent of (or operates independently of) the first door and provides an access to an interior of the near-zero compartment. The overzero compartment is arranged to receive such an air stream from the cooling unit, subzero compartment, and/or near-zero compartment and includes a third door which is independent of (or operates independently of) the first and second doors and arranged to provide an access to an interior of the overzero compartment.

In another exemplary embodiment, such a subzero compartment is arranged to receive the air stream from the cooling unit. The near-zero compartment is rather arranged to receive the air stream from the cooling unit and subzero compartment, and also includes at least one opening arranged to receive and/or disperse a fluid container(s) therethrough. The overzero compartment is arranged to receive the air stream from the cooling unit, subzero compartment, and/or near-zero compartment. In a related exemplary embodiment, the subzero compartment is arranged to receive the air stream from the cooling unit, and the near-zero compartment is arranged to receive the air stream from the cooling unit and/or subzero compartment. The near-zero compartment also includes at least one inlet opening arranged to receive a fluid container therethrough and at least one outlet opening which is generally independent of (or works independently of) the inlet opening arranged to dispense the fluid container therethrough. The overzero compartment is arranged to receive the air stream from the cooling unit, subzero compartment, and/or near-zero compartment.

In yet another exemplary embodiment, the subzero compartment is arranged to receive the air stream from the cooling unit, the near-zero compartment is arranged to receive the air stream from the cooling unit and subzero compartment, and the overzero compartment is arranged to receive the air stream from the cooling unit, subzero compartment, and/or near-zero compartment. The control unit is also arranged to control the amounts of the air streams provided to such compartments and to control a temperature of the near-zero compartment (at least substantially) independently of temperatures of the subzero and overzero compartments. In yet another related exemplary embodiment, the subzero compartment is arranged to receive the air stream from the cooling unit and has a first control switch which operatively couples to the control unit and defines a first range of temperature. The near-zero compartment is arranged to receive the air stream from the cooling unit and subzero compartment and includes a second control switch which is also operatively coupled to the control unit and defines a second range of temperature which is typically arranged to be higher than the foregoing first range. The overzero compartment is further arranged to receive the air stream from the cooling unit, subzero compartment, and/or near-zero compartment and includes a third control switch having a third range of temperature which is typically arranged to be higher than the foregoing second range.

In yet another exemplary embodiment, the subzero compartment is arranged to receive the air stream to maintain its temperature below zero degree, whereas overzero compartment is arranged to receive the air stream to maintain its temperature above zero degree. The near-zero compartment is arranged to receive the air stream to maintain its temperature near (or at, slightly below) zero degree (or at as low a temperature as possible or, alternatively, above that of the subzero compartment and below that of the overzero compartment). The near-zero compartment retains multiple fluid containers as well. The refrigerator includes at least one sensor which is placed in the near-zero compartment, operatively coupled to the control unit, and configured to detect freezing of fluid in the fluid containers. More particularly, such a control unit is arranged to monitor the sensor and to control the temperature of the near-zero compartment over a preset value so as to prevent, e.g., complete freezing of
such a fluid, partial freezing of the fluid beyond a preset extent, expansion of the containers beyond a preset extent by freezing of the fluid, explosion of the containers due to freezing of the fluid, and the like.

[0014] In another aspect of the present invention, refrigerators having other near-zero compartments may also be provided. For example, the refrigerator may include at least one subzero compartment, at least one overzero compartment, and at least one near-zero compartment, a cooling unit, and a control unit. The cooling unit may be arranged to provide a subzero air stream directly to at least one of such compartments and indirectly to the rest of such compartments. The control unit is arranged to control an amount(s) of the air stream(s) supplied to such compartments so as to control a temperature of the subzero and overzero compartments below zero degree and above zero degree, respectively. Such a near-zero compartment may be provided according to various exemplary embodiments.

[0015] In one exemplary embodiment, the foregoing near-zero compartment is arranged to be in fluid communication with the cooling unit and/or subzero compartment and has at least one air inlet through which the air stream may be supplied thereto from the cooling unit and/or subzero compartment. The control unit is arranged to control the amount of the air stream to the near-zero compartment so as to maintain a temperature of the near-zero compartment near (or at, slightly below) zero degree (or at as low a temperature as possible or, alternatively, higher than or above that of the subzero compartment and lower than or below that of the overzero compartment). In another exemplary embodiment, such a near-zero compartment is arranged to define an internal space and to have at least one air inlet and at least one air outlet, where the control unit is arranged to open and close the air inlet and/or air outlet to isolate the near-zero compartment from the subzero and overzero compartments.

[0016] In another exemplary embodiment, such a near-zero compartment may be arranged to receive the air stream from the cooling unit and/or subzero compartment and include multiple retainers which is arranged to occupy at least a substantial portion of one inner surface or plane of such a near-zero compartment to at least partly (or partially) retain fluid containers therein (or thereby). In yet another exemplary embodiment, such a near-zero compartment is arranged to receive the air stream from the cooling unit and/or subzero compartment and to include an own door arranged to provide an access thereto or to an interior thereof but not to (or to interiors of the subzero and overzero compartments. In yet another embodiment, the near-zero compartment is arranged to receive the air stream from the cooling unit and/or subzero compartment and includes at least one opening arranged to receive and/or to dispense a fluid container(s) therethrough. In yet another exemplary embodiment, such a near-zero compartment is arranged to receive the air stream from the cooling unit and/or subzero compartment, includes at least one (container) inlet opening arranged to receive a fluid container therethrough, and also includes (a container) outlet operating which is independent of (or operates independently of) the inlet opening and arranged to dispense the fluid container therethrough.

[0017] In another exemplary embodiment, the near-zero compartment receives the air stream from the cooling unit and/or subzero compartment, where the control unit is arranged to control a temperature of the near-zero compartment (at least substantially) independently of temperatures of the subzero and overzero compartments. In yet another exemplary embodiment, such a near-zero compartment is arranged to receive the air stream from the cooling unit and/or subzero compartment and to include a control switch which is arranged to control a temperature thereof but not temperatures of the subzero and overzero compartments. In yet another exemplary embodiment, such a near-zero compartment is arranged to receive the air stream to keep its temperature near (or at, slightly below) zero degree (or at as low a temperature as possible or, in the alternative, higher than that of the subzero compartment and lower than that of the overzero compartment). The near-zero compartment may be arranged to receive (or retain) multiple fluid containers therein. The refrigerator also includes at least one sensor which is arranged to be placed in the near-zero compartment, operatively coupled to the control unit, and to detect freezing of fluid in the fluid containers. The control unit may be arranged to monitor the sensor and to control the temperature of such a near-zero compartment over a preset temperature to prevent complete freezing of the fluid, partial freezing of the fluid beyond a preset extent, expansion of the containers beyond a preset extent due to freezing of the fluid, explosion of the containers due to freezing of the fluid, and the like.

[0018] Embodiments of the foregoing aspects of the present invention may include one or more of the following features.

[0019] The foregoing near-zero compartment may be disposed in almost any desirable location in, on or around the refrigerator. For example, the near-zero compartment may be disposed in a top portion, a middle portion or a bottom portion of the refrigerator. More particularly, the near-zero compartment may be disposed above or below the subzero (or overzero) compartment, between the subzero and overzero compartments, or inside the subzero (or overzero) compartment. When such a refrigerator may include multiple subzero or overzero compartments, the near-zero compartment may be provided between such multiple subzero (or overzero) compartments. The near-zero compartment may include a separate exterior door which provides an access to an interior thereof. Alternatively, the near-zero compartment may not include the separate exterior door, but share an exterior door with the subzero or overzero compartment. In such an embodiment, the near-zero compartment may include a separate interior door to provide an access to an entire or only a preset portion of the near-zero compartment. In the latter embodiment, optional selectors may also be incorporated into the near-zero compartment to provide an access to its entire portion.

[0020] When desirable, the refrigerator may also include multiple near-zero compartments which may (or may not) be in fluid communication with each other. In the alternative, the near-zero compartment may include multiple sub-compartments which may be arranged to receive the air stream individually (i.e., in a parallel mode) from the cooling unit and/or subzero compartment or in a serial mode (i.e., the air stream flows from one sub-compartment to another). Therefore, the control unit may be arranged to control temperatures of such sub-compartments at the same temperature or different temperatures. The near-zero compartment may include multiple (second) air inlets through which the air
stream may be supplied thereto from the cooling unit and/or subzero compartment. Such plural arrangements may be beneficial in providing the air stream to multiple regions of the near-zero compartment for a uniform temperature distribution therethrough, in facilitating more precise temperature control of the near-zero compartment by supplying various air streams from, e.g., the cooling unit (i.e., the coldest air stream), subzero compartment (i.e., the colder air stream), overzero compartment (i.e., a warmer air stream), and so on. The air path may include two opposing ends one of which is connected to the cooling unit, while the other of which is connected to the air inlet of one of the compartments. Alternatively, one end of the air path may be connected to the air inlet of one compartment, whereas the other end may be connected to another air inlet of another compartment. Such an inter-compartment air path offers a benefit of precisely controlling the temperature of the near-zero compartment as discussed above. In the alternative, the air path may further include three or more ends each of which may be connected to, e.g., the cooling unit and/or one of such compartments.

[0021] The near-zero compartment may have a fixed dimension, i.e., a fixed height, width, and height. Such a dimension may be the same as or less than that of the refrigerator or may be greater than, the same as or less than that of the subzero (or overzero) compartment. In the alternative, the near-zero compartment may be arranged to have an adjustable dimension as well. For example, a mobile divider and/or door may be arranged to move (manually or by the control unit) to define an adjustable internal space of the near-zero compartment. The mobile divider or door may be arranged to adjust a height, a width, and/or a depth of the near-zero compartment to accommodate fluid containers having different shapes and/or sizes. Any residual spaces not occupied by such a mobile divider and/or door may be arranged to join and to operate as the subzero or overzero compartment. The near-zero compartment may also include one or more identical or different retainers arranged to receive identical or different fluid containers. When desirable, such retainers may be arranged to have fixed shapes and/or sizes or adjustable shapes and/or sizes.

[0022] The cooling unit may be arranged to provide the air stream to various compartments according to various arrangements. In one embodiment, the cooling unit may be arranged to provide such an air stream separately or individually to each of the subzero, near-zero, and overzero compartments such that it may directly control the temperature of each compartment separately or individually. In another embodiment, the cooling unit may be arranged in such a way that the air stream is first supplied to the subzero compartment, then to the near-zero compartment from the subzero compartment, and then to the overzero compartment from the near-zero compartment. Other in-between embodiments are also plausible. For example, any of such compartments may receive a first air stream from the cooling unit and a second air stream from other compartments, i.e., such a compartment may include at least two air inlets connected to different sources of the air stream. Similarly, the air pathway from the cooling unit or such compartments may include multiple intake inlets and/or multiple discharging outlets so that a single air pathway may deliver one (or multiple) air stream(s) from one or multiple sources to one or multiple compartments.

[0023] The refrigerator may also include one or more sensors arranged to detect a change in a state of fluids contained in the fluid containers such as, e.g., freezing and/or melting of such fluids. Such sensors may be disposed in the internal space (or interior) of the near-zero compartment to sense the temperature of the internal space (or interior) thereof or to sense the change of states of such fluids. Examples of such sensors may include, but not be limited to, temperature sensors, infrared sensors, volume sensors, mass detection sensors, and so on. For example, pure temperature sensors may be disposed inside the internal space and arranged to sense the temperature of the internal space of the near-zero compartment. Alternatively, such temperature sensors may also be disposed on a surface of the fluid containers (or inside thereof) to sense the temperature of fluids in the containers. Various conventional infrared sensors may be disposed inside the near-zero compartment in order to measure the surface temperature of the fluid containers. Various volume sensors may be arranged to detect a change in a dimension (e.g., a length, width, height, radius, and/or diameter) and/or volume of the fluid container. Such volume sensors may be arranged to contact opposing ends of the container along its dimension and to measure such a dimension or, alternatively, to sense such a dimension at a distance without directly contacting the fluid containers, e.g., by an ultrasonic sensor, an image sensor, and so on. Various mass detection sensors may further be disposed below the fluid container to measure a mass distribution of the fluid container. More particularly, such mass detection sensors are arranged to sense an uneven distribution of the fluid in the fluid container due to partial or complete freezing of such a fluid. Thus, the mass detection sensors may typically be accompanied with other mechanisms to tilt or move the fluid container as will be described in greater detail in the detailed description.

[0024] The refrigerator may include at least one selector unit arranged to move fluid containers inside the near-zero compartment so that an user may position a specific fluid container in a preset location inside such a compartment. Such an embodiment offers a benefit of providing access to almost all of the fluid containers disposed in the near-zero compartment without having to open a door thereof. In addition, at least one image unit may be incorporated such that the user may identify a fluid container disposed in front of or beside a container opening without having to open the door of the near-zero compartment. Examples of such image units may include, but not be limited to, mirrors, prisms, lenses, optical fibers, optoelectric imaging equipment, and the like. The refrigerator may also include at least one mixer arranged to at least partly mix contents of the fluid containers. Such a mixer may enhance cooling of the fluids in the container by removing any temperature gradients and/or thermal boundary layers inside the fluid container.

[0025] In another aspect of the present invention, various near-zero compartments may be provided to a refrigerator having at least one subzero compartment, at least one overzero compartment, at least one near-zero compartment, a cooling unit, and a control unit. The cooling unit is arranged to provide a subzero air stream to at least one of such compartments, and the control unit is arranged to control an amount of the air stream supplied to at least one (or each) of the compartments in order to control temperatures of the subzero, near-zero, and overzero compartments below zero degree, near or at zero degree, and over zero
degree, respectively. Various near-zero compartments may be provided according to various exemplary embodiments.

[0026] In one exemplary embodiment, the near-zero compartment includes a body and at least one air inlet through which such an air stream is supplied into the body from the cooling unit and/or subzero compartment. The control unit is particularly arranged to control the amount of the air stream through the air inlet to maintain a temperature inside the body near (or at, slightly below) zero degree (or at as low a temperature as possible or, alternatively, above or higher than that of the subzero compartment and below or lower than that of the overzero compartment). In another exemplary embodiment, such a near-zero compartment includes a body, at least one air inlet arranged to receive the air stream into the body therefore, and at least one air outlet arranged to discharge the air stream out of the body therefore. The control unit is arranged to open and close the air inlet and air outlet to operatively isolate the near-zero compartment from the subzero and overzero compartment, and also to control the amount of the air stream to maintain a temperature inside the body near (or at, slightly below) zero degree (or as low a temperature as possible or, in the alternative, higher than that of the subzero compartment and lower than that of the overzero compartment).

[0027] In another embodiment, the near-zero compartment has a body and at least one air inlet. Such a body has multiple retainers arranged to occupy at least a substantial portion of an inner surface (or plane) of the near-zero compartment and to at least partially (or partly) retain various fluid containers therein (or thereby). The air inlet is arranged to receive the air stream therethrough from one or both of the cooling unit and/or subzero compartment, and the control unit is arranged to control the amount of the air stream to maintain a temperature inside the body near (or at, slightly below) zero degree (or as low a temperature as possible or, in the alternative, higher than that of the subzero compartment and lower than that of the overzero compartment). In another exemplary embodiment, the near-zero compartment may include a body, at least one air inlet, and at least one door. The air inlet is arranged to receive the air stream supplied into the body from the cooling unit and/or subzero compartment, and the door is arranged to provide an access to an interior of the body but not to interiors of the subzero and overzero compartments. The control unit is then arranged to control the amount of the air stream so as to maintain a temperature inside the body near (or at, slightly below) zero degree (or as low a temperature as possible or, in the alternative, higher than that of the subzero compartment and lower than that of the overzero compartment).

[0028] In another exemplary embodiment, the near-zero compartment includes a body, at least one air inlet through which the air stream may be supplied into the body from the cooling unit and/or subzero compartment, and at least one opening arranged to receive a fluid container therethrough. The control unit is arranged to control the amount of the air stream so as to maintain a temperature inside the body near (or at, slightly below) zero degree (or as low a temperature as possible or, in the alternative, higher than that of the subzero compartment and lower than that of the overzero compartment). In a related exemplary embodiment, the near-zero compartment has a body, at least one air inlet through which the air stream may be supplied into the body from the cooling unit and/or subzero compartment, at least one container inlet arranged to receive at least one fluid container therethrough, and at least one container outlet operating independently of the container inlet and arranged to dispense the fluid container therethrough. The control unit is then arranged to control the amount of the air stream so as to maintain a temperature inside the above body near, at or slightly below zero degree (or at as low a temperature as possible or, in the alternative, higher than that of the subzero compartment and lower than that of the overzero compartment).

[0029] In another exemplary embodiment, the near-zero compartment includes a body and at least one air inlet through which the air stream is supplied into such a body from the cooling unit and/or subzero compartment. The control unit is arranged to control the amount of the air stream in order to maintain a temperature inside the body (at least substantially) independently of temperatures inside the subzero and/or overzero compartments. In another exemplary embodiment, the near-zero compartment has a body, at least one air inlet through which the air stream is supplied into the body from the cooling unit and/or subzero compartment, and at least one control switch arranged to operatively couple with the control unit in order to control a temperature inside the body of the near-zero compartment but not to control temperatures of the subzero and overzero compartments. In another exemplary embodiment, the near-zero compartment has a similar body arranged to retain at least one fluid container, at least one air inlet through which the air stream is supplied into the body from the cooling unit and/or subzero compartment, and at least one sensor arranged to be disposed inside the body, to operatively couple with the control unit, and to detect freezing of fluid in the fluid containers. The control unit is arranged to monitor the sensor and to maintain the temperature inside the body over or above a preset value to prevent complete freezing of the fluid, partial freezing of the fluid beyond a preset extent, expansion of the fluid containers by freezing of the fluid, explosion of the fluid containers due to freezing of the fluid, and the like.

[0030] Various embodiments of such an aspect of this invention may also include one or more of the features which have been described heretofore and/or which are to be described in conjunction with other aspects of this invention.

[0031] In another aspect of the present invention, various methods may be provided for refrigerating different articles at different temperatures using an air stream having a temperature lower than zero degree. Such methods may be provided according to various embodiments.

[0032] An exemplary method may include the steps of providing a first compartment including at least one first air inlet, supplying the air stream to the first compartment through the first air inlet to maintain a temperature thereof substantially (or well) below zero degree or above zero degree, providing a second compartment with at least one second air inlet; and independently supplying the air stream to the second compartment through such a second air inlet in order to maintain its temperature near (or at, slightly below) zero degree (or at as low a temperature as possible). Another exemplary method includes the steps of providing a first compartment, supplying the air stream into the first compartment to maintain its temperature well (or substantially) below zero degree or above zero degree, providing a
second compartment separately from the first compartment, and then supplying the air stream to the second compartment so as to maintain its temperature near (or at, slightly below) zero degree (or at as low a temperature as possible).

[0033] Another exemplary method may include the steps of providing a first compartment, supplying the air stream into the first compartment to maintain its temperature well (or substantially) below zero degree or above zero degree, providing a second compartment, providing at least one retainer on at least a substantial portion of one inner surface (or plane) of the second compartment, and supplying the air stream to the second compartment so as to maintain its temperature near (or at, slightly below) zero degree or at as low a temperature as possible. Another exemplary method may also include the steps of providing a first compartment having a first door arranged to provide an access to an interior thereof, closing such a first door of the first compartment, then supplying the air stream into the first compartment so as to maintain its temperature well or substantially below zero degree or above zero degree, providing a second compartment having a second door independently of the first door so as to provide an access to an interior thereof, closing the second door of the second compartment, and supplying the air stream to such a second compartment to maintain its temperature near (or at, slightly below) zero degree (or at as low a temperature as possible). Another exemplary method may include the steps of providing a first compartment, supplying the air stream into the first compartment so as to maintain its temperature substantially (or well) below zero degree or above zero degree, providing a second compartment having at least one opening, receiving or dispensing at least one fluid container through the opening, and supplying the air stream to the second compartment to control a temperature thereof near (or at, slightly below) zero degree (or at as low a temperature as possible).

[0034] Yet another exemplary method may further include the steps of providing a first compartment, supplying the air stream into the first compartment so as to maintain its temperature substantially (or well) below zero degree or above zero degree, providing a second compartment, and then supplying the air stream to the second compartment to control a temperature thereof near (or at, slightly below) zero degree (or at as low a temperature as possible). Yet another exemplary method may include the steps of providing a first compartment, supplying the air stream to the first compartment to maintain a temperature of such a first compartment substantially (or well) below zero degree or above zero degree, providing a second compartment, installing at least one sensor to the second compartment, measuring a temperature of said second compartment and/or a physical feature of a fluid container disposed in the second compartment, and supplying the air stream to the second compartment so as to maintain a second temperature of the second compartment near (or at, slightly below) zero degree or at as low a temperature as possible independently of the first compartment, while preventing complete freezing of a fluid in the fluid container, partial freezing of the fluid beyond a preset extent, expansion of the container beyond a preset extent, explosion of the container, and so on.

[0035] Various embodiments of such methods of this invention may further include one or more of the features which have been described heretofore and/or which are to be described in conjunction with other aspects of this invention.

[0036] In another aspect of this invention, various methods are provided to refrigerate fluid containers near, at or slightly below zero degree with an air stream having a temperature lower than zero degree thereto. Such methods may be provided according to various embodiments.

[0037] An exemplary method may include the steps of providing a compartment with its own air inlet, supplying the air stream to such a compartment through the air inlet, and adjusting an amount of the air stream to the compartment to maintain the fluid containers near (or at, slightly below) zero degree (or at as low a temperature as possible). Another exemplary method may include the steps of providing a compartment having its own internal space, supplying the air stream to the compartment, and adjusting an amount of the air stream to the compartment to keep the fluid containers near (or at, slightly below) zero degree (or at as low a temperature as possible).

[0038] Another exemplary method may include the steps of providing a compartment, incorporating at least one retainer onto at least a substantial portion (or part) of one inner surface (or plane) of such a compartment, supplying the air stream to the compartment, and adjusting an amount of the air stream to such a compartment to maintain the fluid container near (or at, slightly below) zero degree (or at as low a temperature as possible). Another exemplary method may also include the steps of providing a compartment having its own door to provide an access to an interior thereof, closing the door of such a compartment, supplying the air stream to the compartment, and adjusting an amount of the air stream to the compartment to maintain the fluid containers near, at or slightly below zero degree (or at as low a temperature as possible). In addition, another exemplary method may include the steps of providing a compartment having at least one opening, receiving and/or dispensing a fluid container through such an opening, supplying the air stream to the compartment, and adjusting an amount of the air stream to the compartment to maintain the fluid containers near (or at, slightly below) zero degree (or at as low a temperature as possible).

[0039] Yet another exemplary method may also include the steps of providing multiple compartments, supplying the air stream(s) to the compartments, and adjusting an amount of the air stream supplied to at least one of the compartments to maintain a temperature of such a compartment near (or at, slightly below) zero degree (or at as low a temperature as possible) (at least substantially independently of temperatures of the rest of such compartments. Another exemplary method may include the steps of providing a compartment, installing at least one sensor to the compartment, measuring or monitoring a temperature of the compartment and/or a physical characteristics of the fluid containers disposed in the compartment, supplying the air stream to the compartment, and then adjusting an amount of the air stream to the compartment to maintain the temperature of the compartment near (or at, slightly below) zero degree (or at as low a temperature as possible), while preventing complete freezing of a fluid in the fluid container, partial freezing of the fluid beyond a preset extent, expansion of the fluid container beyond a preset extent, and explosion of the fluid container, and so on.
Various embodiments of such methods of this invention may further include one or more of the features which have been described heretofore and/or which are to be described in conjunction with other aspects of this invention.

In another aspect of the present invention, various methods may provide refrigerators having multiple compartments and capable of maintaining different temperatures in such compartments. Such methods may be provided according to various embodiments. An exemplary method may include the steps of generating an air stream having a temperature below zero degree, supplying the air stream to multiple compartments, controlling an amount of the air stream supplied to a first compartment of such compartments to maintain a temperature of such a first compartment substantially (or well) below zero degree, then controlling an amount of the air stream supplied to a second compartment of the above compartments to maintain a temperature of the second compartment near (or at, slightly below) zero degree (or at as low a temperature as possible), and controlling an amount of the air stream supplied to a third compartment of such compartments so as to maintain a temperature of the third compartment above zero degree.

Another related exemplary method may include the steps of generating a similar air stream having a temperature below zero degree, supplying the air stream to multiple compartments, and controlling an amount of the air stream supplied to at least one of such compartments to maintain its temperature at, near or slightly below zero degree (or at as low a temperature as possible).

Various embodiments of such methods of this invention may further include one or more of the features which have been described heretofore and/or which are to be described in conjunction with other aspects of this invention.

In another aspect of the present invention, various methods may be provided to keep different articles at different preset temperatures. One exemplary method may include the steps of disposing an article in a compartment, supplying an air stream having a temperature below zero degree to such a compartment, and maintaining a temperature of such a compartment near at or slightly below zero degree (or at as low a temperature as possible) but above a preset minimum temperature to prevent complete freezing of the article, partial freezing of the article beyond a preset extent, expansion of the article beyond a preset extent, and the like.

Unless otherwise defined in the following specification, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the present invention belongs. Although the methods or materials equivalent or similar to those described herein can be used in the practice or in the testing of the present invention, the suitable methods and materials are described below. All publications, patents, and/or other references mentioned herein are incorporated by reference in their entirety. In case of any conflict, the present specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only and not intended to be limiting.

Other features and advantages of the present invention will be apparent from the following detailed description, and from the claims.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1A is a schematic diagram of a refrigerator having an exemplary near-zero compartment disposed between a pair of subzero compartment according to the present invention;

FIG. 1B is a schematic diagram of a refrigerator having an exemplary near-zero compartment disposed inside an overzero compartment according to the present invention;

FIG. 1C is a schematic diagram of a refrigerator having an exemplary near-zero compartment disposed beside an overzero compartment according to the present invention;

FIG. 1D is a schematic diagram of a refrigerator having an exemplary near-zero compartment disposed inside an overzero compartment according to the present invention;

FIG. 2A is a front view of a refrigerator having a side-by-side configuration and having various exemplary near-zero compartments in various regions thereof according to the present invention;

FIG. 2B is a front view of a refrigerator having a side-by-side configuration and having various exemplary
near-zero compartments extending in various directions according to the present invention;

[0054] FIG. 2C is a side view of a refrigerator including various exemplary near-zero compartments in various regions thereof according to the present invention;

[0055] FIG. 2D shows a front view of a refrigerator having a vertical configuration and having various exemplary near-zero compartments in various regions thereof according to the present invention;

[0056] FIG. 3A is a block diagram of exemplary paths of subzero air streams independently supplied directly to multiple compartments of a refrigerator according to the present invention;

[0057] FIG. 3B is a block diagram of exemplary paths of subzero air streams sequentially supplied to multiple compartments of a refrigerator according to the present invention;

[0058] FIG. 3C is another block diagram of exemplary paths of subzero air streams sequentially and independently supplied to multiple compartments of a refrigerator according to the present invention;

[0059] FIG. 3D is a block diagram of exemplary paths of subzero air streams independently and partly sequentially supplied to multiple compartments of a refrigerator according to the present invention;

[0060] FIG. 4A denotes a schematic diagram of an exemplary selector unit according to the present invention;

[0061] FIG. 4B is a schematic diagram of an exemplary selector unit with a four-by-eight configuration and moving in a first pattern according to the present invention;

[0062] FIG. 4C is a schematic diagram of an exemplary selector unit with a four-by-eight configuration and moving in a second pattern according to the present invention;

[0063] FIG. 4D is a schematic diagram of an exemplary selector unit with a four-by-eight configuration and moving in a third pattern according to the present invention;

[0064] FIG. 4E is a schematic diagram of an exemplary selector unit with a movable container opening and a mirror according to the present invention.

[0065] FIG. 4F is a schematic diagram of an exemplary selector unit having a fixed container opening according to the present invention.

[0066] FIG. 5A is a schematic diagram of an exemplary sensor unit for detecting dimensional changes due to freezing of fluid in a fluid container according to the present invention;

[0067] FIG. 5B is a schematic diagram of a modified embodiment of the exemplary sensor unit of FIG. 5A according to the present invention;

[0068] FIG. 5C is a schematic diagram of an exemplary sensor unit in its inactive position for detecting uneven distribution of fluid in a fluid container according to the present invention;

[0069] FIG. 5D is a front view of the sensor unit of FIG. 5C according to the present invention;

[0070] FIG. 5E is a schematic diagram of the exemplary sensor unit of FIG. 5C in its active position for detecting uneven distribution of fluid in a fluid container according to the present invention; and

[0071] FIG. 5F is a front view of the sensor unit of FIG. 5E according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0072] The present invention generally relates to a refrigerator including a third compartment arranged to maintain its temperature at, near or slightly below a freezing point of water so that aqueous articles stored therein may be cooled down to their freezing point and completely frozen. More particularly, such a refrigerator typically includes at least one near-zero compartment, where a control unit may be arranged to control temperatures of such a compartment near, at or slightly below zero degree. Such a near-zero compartment is arranged to be in fluid communication with a cooling unit and/or a subzero compartment (i.e., a freezing compartment) to receive a subzero air stream therefrom, and defines an internal space which is preferably not in direct fluid communication with other compartments such that the control unit may control an amount of the air stream and, thereby, the temperature of the near-zero compartment at least substantially independently of the temperatures of other compartments. Such a near-zero compartment of the present invention may be incorporated to any household refrigerators, freezers, industrial refrigerators and/or freezers, household or commercial beverage dispensers, and the like. Such a near-zero compartment may also be manufactured as a separate console designated to chill beverages containers down to their freezing points. Such a near-zero compartment may also be provided as an add-on unit to be retrofit into conventional refrigerators and/or freezers.

[0073] In one aspect of the present invention, a near-zero compartment is provided to a conventional refrigerator. FIGS. 1A to 1D denote schematic diagrams of refrigerators with various exemplary near-zero compartments according to the present invention.

[0074] FIG. 1A is a schematic diagram of a refrigerator having an exemplary near-zero compartment disposed between a pair of subzero compartment according to the present invention. For example, a refrigerator 10 has a side-by-side configuration, where a pair of subzero compartments 20A, 20B are disposed on its left side (when viewed from front) and a single overzero compartment 30 disposed on its right side. A control unit (not shown in the figure) is generally arranged to maintain a temperature of the subzero (or freezing) compartment substantially or well below zero degree (e.g., below -5°C or in some cases below -15°C or -20°C), whereas a temperature of the overzero compartment over zero degree (e.g., about 2°C to 5°C). Such a refrigerator 10 further includes a near-zero compartment 40 which is disposed between the vertically disposed subzero compartments 20A, 20B and includes its own exterior door. FIG. 1B is a schematic diagram of a refrigerator including an exemplary near-zero compartment disposed inside an overzero compartment thereof according to the present invention. A refrigerator 10 also has the side-by-side configuration and includes a subzero compartment 20 and an overzero compartment 30. The near-zero
compartment 40 is disposed as a separate chamber inside the overzero compartment 30. Therefore, the near-zero compartment 40 of this embodiment does not have an exterior door but rather includes its own interior door which provides an access to an interior thereof.

In another aspect of the present invention, a near-zero compartment may be incorporated into almost any region of a refrigerator and in almost any shape and/or size. FIGS. 2A to 2D are schematic diagrams of various near-zero compartments disposed in various regions of exemplary refrigerators according to the present invention. For example, FIG. 2A shows a front view of a refrigerator having a side-by-side configuration and having exemplary near-zero compartments in various regions thereof according to the present invention. A near-zero compartment 40TS, 40MS, 40BS may be respectively incorporated into a top portion, a middle portion, and a bottom portion of a subzero compartment 20. In the alternative, the near-zero compartment 40TO, 40MO, 40BO may also be respectively incorporated into a top portion, a middle portion, and a bottom portion of an overzero compartment 30. Such a near-zero compartment 40 may be arranged to extend length-wise to cover an entire portion of the subzero or overzero compartment 20, 30 or to cover only a portion of the compartments 20, 30. Alternatively, near-zero compartments may further be arranged to extend across both of the subzero and overzero compartments 20, 30. For example, FIG. 2B is a front view of another refrigerator with a side-by-side configuration and including various exemplary near-zero compartments extending in various directions according to the present invention. For example, a near-zero compartment 40HT, 40HM, 40HB may be arranged to horizontally extend across an entire length (or width) of the refrigerator 10 and disposed in a top portion, a middle portion, and a bottom portion of the refrigerator 10, respectively. A near-zero compartment 40VA may be arranged to vertically extend across an entire height of the refrigerator 10 or, in the alternative, such a compartment 40VT, 40VB may be arranged to vertically extend only a portion of the height of the refrigerator 10 and disposed in a top portion and a bottom portion of the refrigerator 10, respectively.

Near-zero compartments may be arranged to extend along various depths into subzero and/or overzero compartments of a refrigerator. FIG. 2C shows a side view of a refrigerator having a side-by-side configuration and including various exemplary near-zero compartments into various depths of the refrigerator according to the present invention. Such a subzero compartment 40DT, 40DM, 40DB may be arranged to extend into an entire depth of the refrigerator 10 (or its compartments 20, 30) and respectively disposed in a top portion, a middle portion, and a bottom portion of the refrigerator 10 (or its compartments 20, 30). Alternatively, a subzero compartment 40ST, 40SM, 40SB may be arranged to be shallow to extend into only a portion of the depth of the refrigerator 10 (or its compartments 20, 30) and to be disposed in a top portion, a middle portion, and a bottom portion of the refrigerator 10 (or its compartments 20, 30). It is appreciated that the foregoing subzero compartments 40 described in conjunction with FIGS. 2A through 2C may be arranged to have any desirable height. For example, a subzero compartment 40SA may be arranged to be shallow to extend into only a portion of the height of the refrigerator 10 (or its compartments 20, 30 thereof) and to be disposed along an entire or only a portion of a height of the refrigerator 10 (or its compartments 20, 30).

The foregoing near-zero compartments may be incorporated into refrigerators having vertical configurations as well. FIG. 2D shows a front view of a refrigerator having a vertical configuration and including various exemplary near-zero compartments in various regions thereof according to the present invention. For example, a near-zero compartment 40TS, 40MS, 40BS may be disposed in a top portion, a middle portion, and a bottom portion of a subzero compartment 20 or, in the alternative, a near-zero compartment 40TO, 40MO, 40BO may be disposed in a top portion, a middle portion, and a bottom portion of an overzero compartment 30. As described above, these near-zero compartments 40 may be arranged to extend along an entire length or only a portion of such a length or width of the refrigerator 10 (or its compartments), and/or to extend into an entire depth or only a portion of such a depth thereof.

Configurational or operational variations or modifications of the exemplary embodiments shown in FIGS. 2A to 2D also fall within the scope of the present invention. First, any of the above near-zero compartments may have any exterior shapes and/or sizes, and define an internal space therein which may have any shapes and/or sizes. Thus, the exterior and/or interior of the near-zero compartments may horizontally extend along any length (or width) and into any depth and vertically extend along any height. Secondly, any of the foregoing near-zero compartments may be arranged to be accessed by an user either directly or indirectly. For example, such a near-zero compartment may include its own exterior door as exemplified in FIGS. 1A and 1C. Alternatively, when the near-zero compartment may be disposed inside the subzero or overzero compartment, it may only include an interior door so that the user can access the interior of the near-zero compartment by opening a door for the subzero or overzero compartment and thereafter opening such an interior door of the near-zero compartment. In addition, the near-zero compartment may be disposed horizontally or vertically between the subzero and overzero compartments as exemplified in FIG. 1A. Furthermore, the near-zero compartment may be incorporated into a front or a back of a door for the subzero or overzero compartment so that the inclusion of the near-zero compartment does not necessarily reduce or sacrifice any internal space of the subzero or overzero compartment.

The foregoing near-zero compartment may also be arranged to have a length, width and height enough to retain fluid containers of specific or preset dimensions. When the
near-zero compartment is arranged to receive and to retain metal can-type containers such as aluminum cans for carbonated beverages, such a compartment may have a height slightly greater than that of the cans when such cans are to be retained upright or may have a width slightly greater than that of the cans when such cans are to be retained sideways. The near-zero compartment may also have dimensions to fit glass bottles for, e.g., carbonated beverages, wine, milk, and/or juices, to fit plastic containers or laminated paper containers for, e.g., drinks and/or juices. When desirable, the near-zero container may include retainers arranged to at least partially hold such containers, where the shapes and/or sizes of such retainers may vary. In addition, such retainers may be arranged to have mobile parts which may be manually moved to adjust dimensions of receiving spaces thereof. The near-zero compartment may be arranged to have an adjustable exterior and/or interior dimensions as well. In this embodiment, the near-zero compartment includes at least one mobile wall or divider, in which the internal space of the near-zero compartment may be determined by a spatial position of the mobile wall. For example, such a mobile wall may be movably disposed to connect the near-zero compartment to one of the subzero or overzero compartment. When the user moves the mobile wall (or divider) away from the near-zero compartment, the mobile wall recruits a space from the subzero or overzero compartment and adds such a space to the near-zero compartment, thereby increasing the internal space of the near-zero compartment. Conversely, when the user moves the mobile wall toward the near-zero compartment, the mobile wall gives up the recruited space from the near-zero compartment, thereby decreasing the internal space of the near-zero compartment.

In another aspect of the present invention, a refrigerator includes at least one cooling unit and a control unit, where the cooling unit generates subzero air streams and the control unit is arranged to distribute (or supply) the subzero air streams directly and/or indirectly to multiple compartments of the refrigerator through various paths or pathways for the air streams. FIGS. 3A through 3D show block diagrams of exemplary paths of subzero air streams of refrigerators and exemplary control schemes of control units according to the present invention.

FIG. 3A is a block diagram of exemplary paths of subzero air streams independently supplied directly to multiple compartments of a refrigerator according to the present invention. In addition to the above subzero, overzero, and near-zero compartments, 20, 30, 40, an exemplary refrigerator 10 also includes a cooling unit 50, a control unit 60, multiple air paths or pathways 11, and a variety of control valves 21, 31A, 41A. Such a cooling unit 50 includes a coolant compressor arranged to compress or liquefy coolant by applying energy thereto, a coolant evaporator for evaporating the liquefied coolant, and a heat exchanger in which the evaporating coolant absorbs heat from an ambient air to generate an subzero air stream having a temperature typically below zero degree. The cooling unit 50 is in fluid communication with various compartments 20, 30, 40 through the air pathways 11 through which the subzero air stream is supplied to various compartments 20, 30, 40. The control unit 60 is arranged to control or adjust an amount of the subzero air stream flowing through the air pathway 11 by opening, closing or metering the control valves 21, 31A, 41A. Because the pathways 11 directly connects the cooling unit 50 to each of the subzero, overzero, and near-zero compartments 20, 30, 40, the control unit 60 of this embodiment may be able to individually control the temperatures of each compartment 20, 30, 40.

In operation, an user sets a preset target temperature for each of the subzero, overzero, and near-zero compartments 20, 30, 40. As described above, the cooling unit 50 provides the subzero air stream and supplies such through the air pathway 11. The control unit 60 monitors the temperatures of the compartments 20, 30, 40, and supplies the subzero air stream to a compartment(s) of which the temperature is higher than its preset target temperature by, e.g., opening or metering a corresponding control valve which connects the cooling unit 50 thereto. When the temperature of the compartment reaches the preset temperature, the control unit 60 closes the corresponding control valve and may also turn off the cooling unit 50 when the temperatures of all compartments 20, 30, 40 respectively reach their preset temperatures. When the temperature of any compartment increases, the control unit 60 turns on the cooling unit 50 and opens the corresponding control valve to supply the subzero air stream to such a compartment, thereby maintaining the temperatures of all compartments 20, 30, 40 at or below their preset temperatures.

The refrigerators of the present invention may be provided with other air pathways according to various embodiments. For example, FIG. 3B shows a block diagram of exemplary paths of subzero air streams which are sequentially supplied to multiple compartments of a refrigerator according to the present invention. In contrary to the air pathways 11 of FIG. 3A which individually connect the cooling unit 50 to each compartment 20, 30, 40, air pathways 11 of FIG. 3B connects the cooling unit 50 to the subzero compartment 20, couples the subzero compartment 20 to the near-zero compartment 40, and then couples the near-zero compartment 40 to the overzero compartment 30. Therefore, the subzero air stream generated by the cooling unit 50 flows in the order of the subzero, near-zero, and overzero compartments, 20, 40, 30. Similar to the embodiment shown in FIG. 3A, various control valves 21, 31B, 41B are disposed along the air pathways 11, and the control unit 60 may open, close or meter each of such valves 21, 31B, 41B to adjust amounts of the subzero air streams through each air pathway 11.

In operation, an user sets a preset target temperature for each of the subzero, overzero, and near-zero compartments 20, 30, 40. The cooling unit 50 provides the subzero air stream and supplies such a stream through the air pathway 11, while the control unit 60 monitors the temperature of each of the compartments 20, 30, 40. When the temperature of the subzero compartment 20 falls below its preset target temperature, the control unit 60 turns on the cooling unit 50 and opens the control valve 21 while closing other valves 31B, 41B so that the subzero air stream is supplied from the cooling unit 50 to the subzero compartment 20, thereby cooling the subzero compartment 20 but not the near-zero or overzero compartment 40, 30. When the temperature of the near-zero compartment 40 falls below the preset temperature but not the temperatures of the other compartments 20, 30, the control unit 60 opens the control valves 21, 31B while closing the other valve 31B such that the subzero air stream is delivered to the near-zero compartment 40 through the subzero compartment 20. Alternatively, when the temperature of the overzero compartment
30 falls below the preset temperature, the control unit 60 opens all control valves 21, 31B, 41B such that the subzero air stream is delivered to the overzero compartment 30 through the subzero and near-zero compartments 20, 40. When the temperatures of all compartments reach their preset target temperatures, the control unit 60 closes all valves 21, 31B, 41B, and turns off the cooling unit 50, while maintaining the temperatures of all compartments 20, 30, 40 at or below their preset temperatures.

[0086] The refrigerators of this invention may include combinational embodiments of the air pathways shown in FIGS. 3B and 3C. For example, FIG. 3C is a block diagram of exemplary paths of subzero air streams sequentially and independently supplied to multiple compartments of a refrigerator according to the present invention, where air pathways 11 connect the cooling unit 50 to each compartment 20, 30, 40 and connect one compartment to the other as well. The refrigerator 10 further includes various control valves 21, 31A, 31B, 41A, 41B each of which is individually opened and closed by the control unit 60. Accordingly, the control unit 60 may deliver the subzero air stream to one compartment either directly from the cooling unit 50 or through other compartments. In another example, FIG. 3D is a block diagram of exemplary paths of subzero air streams independently and partly sequentially provided to multiple compartments of a refrigerator according to the present invention. The embodiment of FIG. 3D is similar to that of FIG. 3C, except that the one of FIG. 3D does not include the air pathway connecting the subzero and near-zero compartments 20, 40.

[0087] Configurational or operational variations or modifications of the exemplary embodiments shown in FIGS. 3A to 3D also fall within the scope of the present invention. First of all, the refrigerators of the present invention may employ a variety of cooling mechanisms and/or control mechanisms as long as they can maintain a temperature inside the near-zero compartment at a preset temperature which may be at, near or slightly below zero degree. Therefore, detailed configurations of the cooling and control units are not material to the scope of the present invention. Secondly, the above cooling units of FIGS. 3A to 3D may be substituted by various functionally equivalent cooling mechanisms. For example, the cooling unit may generate the subzero air stream may have a temperature varying over a wide range, e.g., from a few degrees above zero degree down to −20°C or so, although it is desirable to lower the temperature of the air stream as low as possible to facilitate heat transfer by as great a temperature gradient as possible, i.e., unsteady heat transfer. Instead of the above forced convection mechanism of providing the subzero air stream, other cooling medium may also be employed. For example, such a cooling unit may be arranged to circulate a coolant by, e.g., compressing the coolant, evaporating the coolant, supplying such a coolant directly to the subzero, near-zero, and overzero compartments, and circulating such a coolant to the compressor for a next compression. Alternatively, coolant pathways may be provided through each compartment and the subzero coolant may be arranged to flow inside the coolant pathways. Then, the subzero coolant may absorb heat energy in the compartment not by convectional heat transfer but by conductive heat transfer. Combination of the foregoing conduction and forced convection mechanisms may also be employed. Thirdly, the above air pathways may also be arranged to provide different fluid communications among the cooling unit and compartments and/or among such compartments. For example, the air pathway may have more than one inlet and/or more than one air outlet so that the subzero air stream may be delivered to multiple compartments and/or be collected from multiple compartments. Fourthly, an air stream having a higher temperature may also be provided to the compartment of which an internal temperature is lower than such an air stream. For example, the control unit may be arranged to supply, when desirable, the ambient air to the near-zero compartment or the subzero air stream from the overzero compartment to the near-zero compartment. This embodiment offers a benefit of instantly increasing the temperature of the near-zero compartment and preventing over-freezing of fluids in the fluid containers placed therein.

[0088] In another aspect of the present invention, a refrigerator may include at least one selector unit arranged to move fluid containers inside the foregoing near-zero compartments. Such an embodiment offers a benefit of providing capabilities of selecting a specific fluid container regardless of where the fluid container is disposed inside the near-zero compartment. FIGS. 4A to 4F are schematic diagrams of exemplary selector units for moving fluid containers according to the present invention.

[0089] FIG. 4A shows a schematic diagram of a first exemplary selector unit according to the present invention. A selector unit 70 includes multiple holders 71 each of which forms an opening 72 which is arranged to at least partly retain a fluid container therein or thereby. The holders 71 are mechanically coupled to each other by couplers 73 so that a motor or other actuating units may move such holders 71, e.g., in a counterclockwise direction, similar to conventional conveyor belts used in baggage claim sections in airports. Accordingly, an user may move the holders 71 along a preset direction and then position a specific holder 71 in a preset location inside the near-zero compartment.

[0090] FIG. 4B is a schematic diagram of an exemplary selector unit with a four-by-eight configuration and moving in a first pattern according to the present invention. Contrary to the above selector unit 70 having a double-row arrangement (i.e., a front row and a back row of holders 71), a selector unit 70 shown in FIG. 4B arranges twenty-four holders 71 in a four by six formation, where each holder 71 is mechanically coupled to two other adjacent holders 71. A motor or actuating unit is arranged to move the holders 71 such that the holder 71, e.g., disposed in a right lower corner, moves from right to left along a bottom row to a left lower corner, to a left upper corner therefrom along a first left column, to a right upper corner therefrom along a top row, one row downward therefrom, from right to left along a second top row, one row downward again therefrom, from left to right along a third top row, and to its original position therefrom. Therefore, the user may move any holder 71 of the selector unit 70 and position the specific holder 71 in a preset location inside the near-zero compartment. FIG. 4C shows a schematic diagram of another exemplary selector unit with a four-by-eight configuration and moving in a second pattern according to the present invention. A selector unit 70 of this figure is identical to the one of FIG. 4B, except that holders 71 move along a different second pattern. For example, the holder 71 disposed in a right lower corner moves from right to left along a bottom row to a left lower corner, to a left upper corner therefrom along a first left
column, to right into an adjacent slot of a second left column, downward therefrom by two slots to a third top row, to right to an adjacent slot of a third left column, and upward therefrom by two slots to a top row. Such a holder 71 continues the downward and upward movements until it is positioned in the right upper corner. The holder 71 then moves back to its original position downward along a right-most column. FIG. 4D shows a schematic diagram of yet another exemplary selector unit having a four-by-eight configuration and moving in a third pattern according to the present invention. A selector unit 70 of FIG. 4D is identical to those of FIGS. 4B and 4C, except that holders 71 are arranged to move along another third pattern. Therefore, the holder 71 disposed in a right lower corner may move from right to left along a bottom row to a left lower corner, to a left upper corner along a first left column, to right by two slots along a top row therefrom to a third left column, downward therefrom by one slot to a second top row, to left by two slots along a second top row therefrom, downward therefrom by one slot to a third top row, then from left to right along the third top row to a second right column, upward therefrom by one slot to the second top row, to left by two slots to a third right column therefrom, upward therefrom by one slot again to the top row, then to a right upper corner along the top row, and finally downward along a right-most column to its original position.

In operation, the selector unit 70 is either horizontally or vertically installed inside the near-zero compartment 40 and disposes fluid containers inside each opening 72 of the selector unit 70. As the user closes the door of the compartment 40, a control unit 60 turns on a cooling unit 50 and provides a subzero air stream into the compartment 40 while maintaining a temperature in the compartment 40 at, near or slightly below zero degree and/or at other preset temperatures. When the user wants to take a fluid container out of the compartment 40, he or she opens the door and selects one container therefrom. When the container to be selected is disposed deep inside the compartment 40, the user may actuate the selector unit 70, move the holders 71, positions the container in a front row of the selector unit 70, and takes out the container. Similarly, the user may use the selector unit 70 to place fluid containers to the holders 71 of the front row and to move them to back rows of the selector unit 70, thereby utilizing all available space of the near-zero compartment 40.

As described above, the control unit 60 of the refrigerator of this invention is arranged to keep the temperature of the subzero compartment 20 substantially below zero degree and the temperature of the overzero compartment 30 a few degrees above zero degree. Accordingly, the temperatures of such subzero and overzero compartments 20, 30 may deviate a few degrees higher or lower without causing any serious problems in keeping various articles frozen or fresh. It is appreciated, however, that the temperature of the near-zero compartment 40 may be controlled with a higher resolution, for lowering the temperature of such a compartment 40 may freeze fluids of the fluid containers, resulting in rupture and/or explosion of such containers. One embodiment for facilitating a precise temperature control of the near-zero compartment 40 may be to minimize a heat influx into such a compartment 40 while loading or dispensing fluid containers into or out of the compartment 40, respectively. For this purpose, the near-zero compartment 40 of a first embodiment may include a narrow auxiliary door in addition to an exterior or interior door. The user then opens the exterior or interior door and opens the auxiliary door to dispose or dispense the fluid container. By arranging such an auxiliary door to slide to open and to close, heat loss may further be minimized. The near-zero compartment 40 of a second embodiment may include a narrow opening for disposing and dispensing the fluid containers instead of conventional exterior or interior doors. Following FIGS. 4E and 4F describe two exemplary selector units for such a second embodiment.

FIG. 4E is a schematic diagram of a selector unit with an exemplary movable container opening and an exemplary mirror according to the present invention, where a selector unit 70 shown in FIG. 4E is identical to that of FIG. 4B. The near-zero compartment 40 is arranged to retain the selector unit 70 therein and bound by a fixed exterior body 74. The near-zero compartment 40 is also arranged such that its internal space may be accessible through a movable container opening 75 which is arranged to open and close by rotating about a pivot 76. A separate motor or actuator is incorporated to move the holders 71 of the selector unit 70 along the first pattern so that the user may not only dispose but also dispense the fluid containers disposed inside the near-zero compartment 40. In order to facilitate the selection of the fluid containers, a mirror 77 or other imaging unit is disposed beside or next to the movable opening 75 such that the user may identify whether the fluid container disposed next to or in front of the movable opening 75 is what he or she wants. FIG. 4F represents a schematic diagram of a selector unit having an exemplary fixed container opening according to the present invention, where a selector unit 70 of FIG. 4F is identical to that of FIG. 4A. The near-zero compartment is arranged to retain the selector unit 70 therein and bound by a fixed exterior body 74 which forms a fixed container opening 78 through which the user disposes and dispenses the fluid containers. An additional cover may be movably disposed in front of the fixed opening to minimize heat transfer therethrough.

In operation, the user installs the selector unit 70 horizontally or vertically inside the near-zero compartment 40, opens the movable opening 75 of the near-zero compartment 40, and disposes fluid containers inside each opening 72 of the selector unit 70 by moving the holders 71 one after the other through the opening 75. As the user finishes loading the fluid containers and closes the opening 75, a control unit 60 turns on a cooling unit 50 and provides a subzero air stream into the compartment 40 to maintain a temperature inside the compartment 40 at, near or slightly below zero degree or at another preset temperature. When the user wants to dispense a fluid container out of the compartment 40, he or she identifies through the mirror 77 which container is disposed in front of the movable opening 75. When such a container is what the user wants, he or she opens the opening 75 and dispenses such a container therethrough. However, when the container disposed in front of the opening 75 is not the one to be selected, the user moves the holders 71 one by one until he or she finds the desirable fluid container in front of or beside the opening 75. The user then opens the opening 75 and dispenses the fluid container. The user may use the movable opening and mirror to dispense the fluid containers into empty holders 71. For example, the user moves the holders one by one until he or she finds an
empty holder 71. The user opens the movable opening 75 and loads a fluid container therein, and so on.

The fluid containers may be correspondingly placed either horizontally or vertically in the openings of such holders depending upon a height and/or width of the near-zero compartment. The selector units may be arranged to include any number of rows and/or columns as long as the motor or actuator may be able to move each holder of the selector units in an appropriate pattern. Therefore, the selector units may arrange the holders in order to form a rectangle, a square, a diamond, a triangle, a circle, an oval, and the like, where the holders may be disposed at vertices, along sides, and/or in an interior of such configuration. Contrary to the exemplary embodiments shown in FIGS. 4A to 4D, the holders of the selector units may be divided into two or more groups, and the holders which belong to the same group are connected to each other by the couplers but not to the holders of the other groups. In such an embodiment, the motor or actuator moves the holders of each group separately without any inter-group movements.

The holder units may also be arranged to include multiple layers of which the multiple holders arranged in one of the foregoing configurations. In such an embodiment as well, the holders of different layers may be coupled by appropriate couplers such that the holders may move from one region of one layer to different regions of different layers. Alternatively, the holders of different layers may not be coupled to each other such that the holders may move from one region to different regions of the same layer but not to regions of other layers. In this embodiment, each layer may be provided with a separate movable or fixed opening to provide access to the user.

The holders and/or openings thereof of the foregoing selector units may be arranged to have fixed dimensions which fit presected containers such as metal cans, plastic bottles, laminated paper containers, and so on. The holders and/or openings thereof may also be arranged to have adjustable dimensions such that they may retain a variety of containers having different dimensions. A variety of couplers may also be used to connect various holders of the selector units. In order to accommodate curvilinear movements of the holders in various movement patterns, the couplers may be arranged to allow translation or rotation of such holders therealong or therearound. Any conventional mechanical holders may be employed to movably couple the couplers. The holders of such selector units may be arranged to be moved manually by the user or, alternatively, to be moved by an electric motor or other conventional actuators as well. At least one control switch may be incorporated so that the user may start and stop movements of the holders whenever he or she positions a desirable fluid container in a preset location around the selector unit. As described in FIG. 4E, the near-zero compartment may also include imaging units arranged to provide visual images of fluid containers disposed in front of or next to the fixed and/or movable container opening. In addition to the mirrors of the exemplary embodiment of FIG. 4E, such a see-through window may be disposed in a front row of the selector units such that the user may identify the fluid containers disposed in such a row. A micro-camera may also be used to provide images of the fluid containers disposed in front of or beside the fixed or movable container opening and/or fluid containers adjacent such an opening. Other conventional imaging equipment may also be used to provide the foregoing images.

It is appreciated that not all near-zero compartments of this invention may require the foregoing selector units. For example, when the near-zero compartment defines an internal space which has a height and/or a width enough to allow the user to reach the fluid containers disposed in any portion of the internal space, such a compartment may not require any selector unit at all. When the near-zero compartment defines a limited internal space, however, it is crucial to economically utilize a real estate of such a compartment. Accordingly, when the user may not be able to access the fluid containers disposed in the back of the near-zero compartment, the above selector unit may then be incorporated into such a compact near-zero compartment in order to allow the user to select any fluid container he or she wants. The above selector units may also prove useful regardless of the size of the internal space of the near-zero compartment. In one exemplary embodiment, the all pathway to the near-zero compartment may be localized in one region of such a compartment, which may result in an uneven temperature distribution. By incorporating the above selector units, all or at least a substantial portion of the fluid containers may be cooled down to the same or at least a substantially similar temperature, thereby avoiding overcooling or freezing of the fluid containers in one region of such a compartment. In another exemplary embodiment, the selector unit may be utilized to mix the fluids of the containers to facilitate heat transfer. When the fluid container at room temperature is disposed inside the near-zero compartment, the fluid begins to lose its thermal energy because of a huge temperature gradient therebetween. As the heat transfer ensues, the temperature of the fluid disposed near the container wall may drop to that of the compartment, while the temperature of the core fluid remains at the room temperature, thereby developing a thermal boundary layer and hindering heat transfer. To break such a thermal boundary layer, the selector unit may be arranged to at least minimally shake or tilt the fluids of the containers such that the fluids near the container wall may be mixed with the core fluids. In yet another exemplary embodiment and as will be described in greater detail below, the refrigerator of the present invention may include at least one sensor unit arranged to detect a partial and/or complete freezing of the fluids in the containers. When such a sensor unit is disposed only in one region of the near-zero compartment, the selector unit may be used to manually or automatically move the selected containers to the sensor unit so that the sensors of the sensor unit may monitor the temperatures of fluids in different fluid containers.

In another aspect of the present invention, a refrigerator may also include at least one sensor unit arranged to monitor a temperature of a fluid container and/or phase change of fluids contained in the fluid container inside the foregoing near-zero compartments. FIGS. 5A to 5F represent schematic diagrams of exemplary sensor units for detecting freezing of fluid in fluid containers according to the present invention.
FIG. 5A is a schematic diagram of an exemplary sensor unit for detecting dimensional changes due to freezing of a fluid in a fluid container according to the present invention. An exemplary sensor unit 80 has a first arm 81, a second arm 82, and a movable arm 84. The first arm 81 is generally fixed to a body or wall of the near-zero compartment 40, and the second arm 82 is movable coupled to the first arm 81 by a pivot 83 and to rotate thereabout. The movable arm 84 is arranged to translate along the second arm 82 and biased toward the first arm 81. Therefore, when a fluid container is disposed between the first arm 81 and movable arm 84, the sensor unit 80 monitors a distance and/or a change therein between the first and movable arms 81, 84.

In operation, an user selects a fluid container to be monitored by the sensor unit 80. The user rotates the second arm 82 (along with the movable arm 84) to provide a space for the fluid container, places the fluid container therein upright or sideways while abutting the first arm 81, and rotates the second arm 82 toward the fluid container back to its original position. The user translates the movable arm 84 and then abuts an opposite side of the fluid container thereby. The sensor unit 80 monitors a distance between the first and movable arms 81, 84 and detects a change thereof. When the sensor unit 80 detects an increase in the distance which is caused by freezing of the fluids in the container, it generates and sends a control signal to the control unit 80 which in turn shuts down the supply of the subzero air stream to the near-zero compartment 40 and/or which turns on a warmer ambient air thereto.

FIG. 5B is a schematic diagram of a modified embodiment of the exemplary sensor unit of FIG. 5A according to the present invention. A sensor unit 80 of FIG. 5B is similar to that of FIG. 5A, except that the former unit 80 does not include a second arm. The sensor unit 80 of FIG. 5B rather includes a first arm 81 similar or identical to that of FIG. 5A, and a movable arm 84 which is arranged to translate along an opening 85 provided on a wall or body of the near-zero compartment 40. The movable arm 84 is also arranged to be biased toward the first arm 81 so that the sensor unit 80 monitors a distance and/or a change therein between the first and movable arms 81, 84 when the fluid container is placed therebetween. Operational characteristics of the sensor unit 80 of FIG. 5B are at least substantially similar or identical to those of FIG. 5A.

FIG. 5C is a schematic diagram of an exemplary sensor unit in its inactive position for detecting uneven distribution of fluid in a fluid container and FIG. 5D is a front view of the sensor unit of FIG. 5C according to the present invention. In addition, FIG. 5E denotes a schematic diagram of the exemplary sensor unit of FIG. 5C in its active position for detecting uneven distribution of fluid in a fluid container and FIG. 5F is a front view of the sensor unit of FIG. 5E according to the present invention. As shown in the figures, a sensor unit 80 includes a movable or tiltable actuator 86 arranged to receive the fluid container thereon. Such an actuator 86 is arranged to rotate or tilt about a pivot 89, and/or otherwise move between an inactive position (FIGS. 5C and 5D) and an active position (FIGS. 5E and 5F). Such an actuator 86 includes a flat part 91 on one end and a curved part 88 on an opposite end, where the flat part 87 is generally arranged to be flush with a bottom surface of the near-zero compartment 40 and the curved part 88 is slightly raised thereover in the inactive position, and where the flat part 87 is raised over the bottom of the compartment 40 and the curved part 88 is lowered to be generally flush with the bottom surface of the compartment 40 in the active position.

In operation, the actuator 86 is disposed in its inactive position such that its flat part 87 is flush with the bottom surface of the near-zero compartment 40. A fluid container is then disposed over the actuator 86, more particularly, on the flat part 87 or between the flat and curved parts 87, 88 thereof as shown in FIGS. 5C and 5D. As the control unit 60 begins to provide the subzero a stream into the near-zero compartment 40, the sensor unit 80 initiates a series of steps to detect uneven distribution of mass of fluids in the fluid container. For example, the sensor unit 80 rotates or tilts the actuator 86 form its inactive position to its inactive position, e.g., by raising the flat part 87 of the actuator 86 while lowering the curved part 88 thereof. Such a change in contour renders the fluid container roll down along the actuator 86 from the flat part 87 toward the curved part 88 as described in FIGS. 5E and 5F. When the contents of the container are not frozen, they remain in a liquid state and are redistributed in the container so that a meniscus 13 of the fluid is defined on a top of the container as shown in FIGS. 5D and 5F. When the contents are completely frozen, the meniscus 14 of the fluid also rotates along with the container and disposed at an angle as shown in FIG. 5F. Because of such an uneven mass distribution, the container tends to roll back to its original position. The sensor unit then detects such a rolling of the container and sends a control signal to the control unit which then terminatases the supply of the subzero air stream to the near-zero compartment 40 or which supplies an ambient air thereto in order to prevent bursting of the container. Thereafter, the sensor unit 80 may move the actuator 86 back to its inactive position for a next detection procedure. In the alternative, the actuator 86 may be kept in its active position until the next detection procedure during which the actuator 86 is moved to its inactive position and the sensor unit 80 determines whether or not the fluid is evenly distributed in the fluid container.

Configuration or operational variations or modifications of the exemplary embodiments shown in FIGS. 5A to 5F fall within the scope of the present invention. Various conventional sensors may be used to monitor the temperature of the fluid in the container and/or to detect the phase change of such fluid in the container, partial or complete freezing of the fluid, and so on. First of all, any conventional sensors for measuring dimensions may be employed into the sensor units of the present invention to measure, e.g., lengths of the fluid containers, widths thereof, diameters or perimeters thereof, and so on, and to detect the phase change or freezing therefrom. Such sensors may be mechanical sensors or electrical sensors, where the electrical sensors may be arranged to monitor electric voltage, current, resistance, capacitance and/or inductance, changes thereof, and so on. Such dimensional sensors may be utilized to monitor volumes of the fluid containers and/or their changes and to detect the phase change of the fluids or freezing thereof. Secondly, pure temperature sensors may be used to directly or indirectly monitor the temperature of the fluid container and/or fluid itself. Such sensors may be disposed on a surface of the container or, when desirable, inside the container. Thirdly, conventional infrared sensors may be utilized to measure the surface and/or internal temperature of the containers. It is noted, however, that the infrared sensors are generally prone to sense the surface temperature but not that of the fluid inside the container. In order to increase accuracy of such measurement, any mixing mechanisms may be incorporated into the sensor unit so that the
surface temperature of such a container approximates an average temperature of the fluids inside the container. In addition, such mass distribution detection sensor units described herein above may be provided in various modified embodiments. For example, the actuator may be arranged to have a U-shaped cross-section or a V-shaped cross-section, to receive the fluid container therein, and to only slightly tilt the container from one side to the other to detect the uneven mass distribution.

[0105] Contrary to the foregoing embodiments where the preset target temperature of the near-zero compartment is determined based on the phase change and/or freezing of the fluids in the containers, the sensor units may also be arranged to determine the preset target temperature of such a near-zero compartment a priori by types of fluids of the fluid containers. For example, the sensor unit may have an input panel with which the user may select a proper type of the fluids such as, e.g., carbonated beverages, fruit juices, wine, beer, and so on. The sensor unit may also be arranged to count a total number of containers or their total mass disposed in such a compartment, and the control unit may be arranged to control the amount of the subzero air stream supplied therein. When the sensors of such sensor units need a reference point for temperature measurement, the sensor unit may divert a small amount of tap water which is supplied to, e.g., an ice maker of the refrigerator, measure the freezing point of water, and use such a point as the reference.

[0106] The foregoing exemplary refrigerators of the present invention and near-zero compartments of such refrigerators may be substituted by their functional equivalents or modified according to various embodiments. For example, the refrigerator may incorporate multiple similar and/or asimilar near-zero compartments. In the alternative, a single near-zero compartment may be arranged to define multiple sub-sections. The cooling and/or control units may be arranged to maintain the same temperature for all of such compartments and/or sub-sections or to maintain different temperatures in at least two of such compartments and/or sub-sections.

[0107] The foregoing near-zero compartment of the refrigerators of this invention may be arranged to be equipped with a quenching mechanism with which fluid containers disposed therein may be cooled at a faster speed. In such an embodiment, the control unit is arranged to vary the temperature inside the near-zero compartment based on a preset temperature profile including, e.g., an initial fast cooling period during which the temperature inside such a compartment is maintained well below zero degree and a final soaking period during which the temperature inside the compartment is maintained near, at or slightly below (or even above) zero degree. During the initial cooling period, the fluids near the wall of the fluid container may be cooled well below zero degree (and frozen), while the fluids away from and in a core of the container retain most of their thermal energy. During the final soaking period, the fluids near the wall and those away from the wall are allowed to approach an equilibrium and to attain a relatively even temperature distribution. Alternatively, the refrigerator may include a quenching unit which may be incorporated into the near-zero compartment or provided as a separate unit. In such an embodiment, the near-zero compartment is arranged to maintain a constant target temperature, while the quenching unit is generally arranged to have a temporally varying temperature profile to cool fluid containers at a higher speed. In all of the foregoing embodiments, the control unit may be arranged to calculate or to estimate an amount of thermal energy taken away from the fluid containers based on various sensors capable of measuring an amount of heat transfer, temperature changes, etc.

[0108] It is appreciated that the foregoing near-zero compartments may be manufactured as individual units which may be retrofit to existing refrigerators and/or freezers. For example, a retrofitable near-zero compartment may be provided as a sealed compartment having at least one inlet and at least one outlet and arranged to be fitted either into the subzero compartment and/or overzero compartment. In either embodiment, a first air inlet may be arranged to be in fluid communication with an interior of the subzero compartment, whereas a second air inlet may be arranged to be in fluid communication with an interior of the overzero compartment or with ambient air. A control unit is also incorporated into the retrofittable compartment and arranged to open and close the first and second air inlet to maintain the temperature of the retrofittable compartment at, near or slightly below zero degree, e.g., by supplying the subzero air stream to decrease its temperature and by further supplying the less colder air stream from the overzero compartment or ambient air to increase its temperature.

[0109] It is also appreciated that the foregoing near-zero compartments may be incorporated into any household and/or industrial equipment designed to keep various articles at preset temperatures and/or at temperatures other than the room temperature or ambient temperature. Accordingly, the near-zero compartment of this invention may be incorporated into conventional refrigerators having subzero (or freezing) compartments and overzero (or fresh) compartments, conventional freezers having one or multiple subzero compartments, conventional compact refrigerators with the overzero compartments and optional subzero sections which are generally open to the overzero compartments, conventional portable refrigerators or freezers, conventional vegetable refrigerators with one or more overzero compartments and no subzero compartment, and the like, regardless of whether such refrigerators or freezers may be of an upright American style or a flat European style.

[0110] It is to be understood that, while various aspects and/or embodiments of the present invention have been described in conjunction with the detailed description thereof, the foregoing description is intended to illustrate and not to limit the scope of the invention, which is defined by the scope of the appended claims. Other embodiments, aspects, advantages, and modifications are within the scope of the following claims.

What is claimed is:

1. A near-zero compartment of a refrigerator including at least one subzero compartment, at least one overzero compartment, at least one near-zero compartment, at least one cooling unit, and at least one control unit, wherein said cooling unit is configured to provide a subzero air stream to at least one of said subzero, overzero, and near-zero compartments and wherein said control unit is configured to control an amount of said air stream supplied to each of said compartments to control temperatures of said subzero, near-zero, and overzero compartments below zero degree, near zero degree, and over zero degree, respectively, said near-zero compartment comprising:
a body; and

at least one air inlet through which said air stream is supplied into said body by at least one of said cooling unit and subzero compartment,

wherein said control unit is configured to control said amount of said air stream through said air inlet in order to maintain a temperature inside said body at least one of near, at, and slightly below zero degree.

2. The near-zero compartment of claim 1, wherein said control unit is configured to open and to close said air inlet to operatively isolate said near-zero compartment from said subzero and overzero compartments.

3. The near-zero compartment of claim 1, wherein said body is configured to include a plurality of retainers which are configured to occupy at least a substantial portion of one inner surface of said body and to at least partially retain fluid containers therein.

4. The near-zero compartment of claim 3, wherein at least a substantial number of said retainers are configured to have fixed dimensions.

5. The near-zero compartment of claim 3, wherein at least a substantial number of said retainers are configured to have adjustable dimensions.

6. The near-zero compartment of claim 1 further comprising at least one door configured to open and close and to provide an access to an interior of said body but not to interiors of said subzero and overzero compartments.

7. The near-zero compartment of claim 1, wherein said body is configured to define at least one inlet opening configured to receive a fluid container therethrough.

8. The near-zero compartment of claim 8, wherein said body is configured to define at least one outlet opening configured to dispense said fluid container therethrough.

9. The near-zero compartment of claim 1, wherein said control unit is configured to control said amount of said air stream in order to maintain said temperature inside said body at least substantially independently of temperatures inside said subzero and overzero compartments.

10. The near-zero compartment of claim 9, wherein said control unit includes at least one control switch which is configured to be operatively coupled to said control unit and to control said amount of said air stream.

11. The near-zero compartment of claim 1 wherein said body is configured to retain a plurality of fluid containers further comprising:

- at least one sensor unit configured to be disposed inside said body, to operatively couple with said control unit, and to detect freezing of fluid in said fluid containers.
- wherein said control unit is further configured to monitor said sensor unit and to maintain said temperature inside said body over a preset value to prevent at least one of complete freezing of said fluid, partial freezing of said fluid beyond a preset extent, expansion of said containers, and explosion of said containers.

12. The near-zero compartment of claim 11, wherein said sensor unit is configured to monitor at least one of a dimension of said fluid container and a change in said dimension.

13. The near-zero compartment of claim 11, wherein said sensor unit is configured to monitor at least one of a temperature inside said near-zero compartment and a temperature of a surface of said fluid container.

14. The near-zero compartment of claim 11, wherein said sensor unit is configured to monitor an uneven mass distribution inside said fluid container.

15. A refrigerator having a plurality of compartments, a cooling unit, and a control unit, said cooling unit configured to supply a subzero air stream directly to at least one of said compartments and then indirectly to the rest of said compartments, and said control unit configured to control amounts of said air streams supplied to said compartments in order to control temperatures of said compartments, said refrigerator comprising:

- at least one subzero compartment configured to receive said air stream from said cooling unit;
- at least one near-zero compartment configured to receive said air stream from at least one of said cooling unit and subzero compartment; and
- at least one overzero compartment configured to receive said air stream from at least one of said cooling unit, subzero compartment, and near-zero compartment,

wherein said control unit is configured to control a temperature of said near-zero compartment at least substantially independently of temperatures of said subzero and overzero compartments.

16. A method of refrigerating fluid containers by providing an air stream with a temperature lower than zero degree thereunto comprising the steps of:

- providing a first compartment including its own air inlet;
- supplying said air stream to said first compartment through said air inlet; and
- controlling an amount of said air stream to said first compartment in order to maintain said fluid containers at least one of near, at, and slightly below zero degree.

17. The method of claim 16, said providing step comprising the step of:

- defining in said first compartment a separate internal space which is not in fluid communication with other compartments.

18. The method of claim 16 further comprising the steps of:

- providing a door to said first compartment; and
- providing an access to an interior of said first compartment through said door.

19. The method of claim 16 further comprising the steps of:

- providing at least one second compartment; and
- adjusting an amount of said air stream supplied to said first compartments in order to maintain a temperature of said first compartment independently of temperatures of said second compartment.

20. The method of claim 16 further comprising the steps of:

- disposing at least one fluid container in said first compartment;
- incorporating at least one sensor to said first compartment;
sensing at least one of a temperature of said first compartment and a physical characteristics of said fluid containers disposed in said first compartment; and

preventing at least one of complete freezing of fluids in said containers, partial freezing of said fluids beyond a preset extent, expansion of said containers beyond a preset extent, and explosion of said containers by controlling said amount of said air stream supplied to said first compartment.

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