Nov. 30, 1954 G. MUFFLY 2,695,502

ICE-MAKING APPARATUS

Filed Nov. 14, 1950 2 Sheets-Sheet 1

FIG. 1.

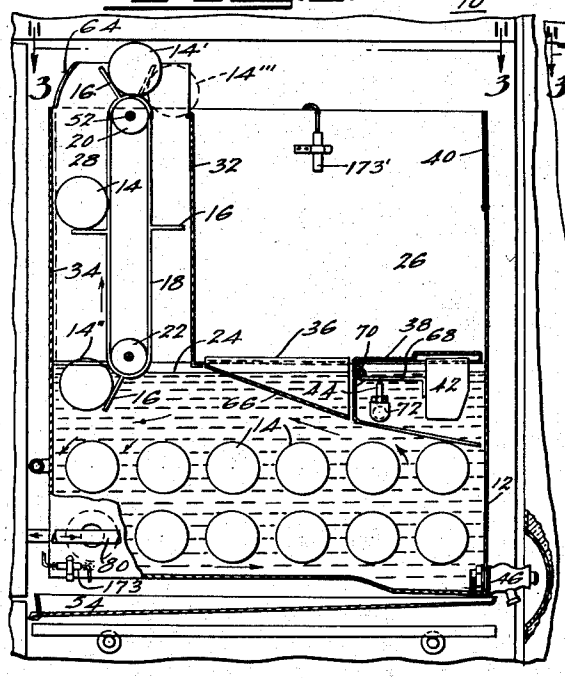


FIG. 2.

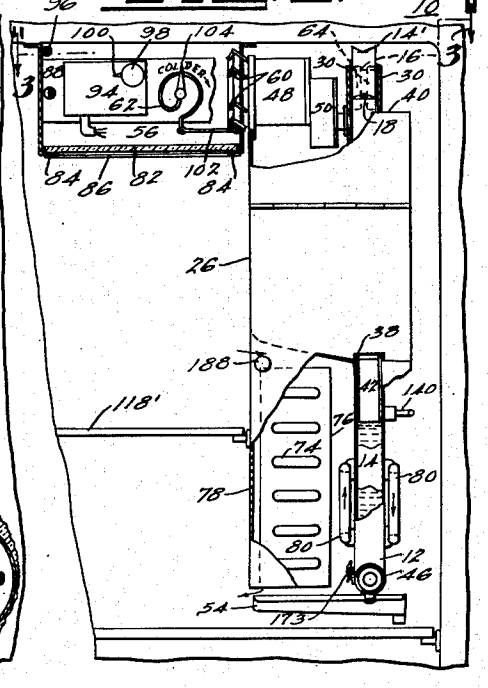


FIG. 3.

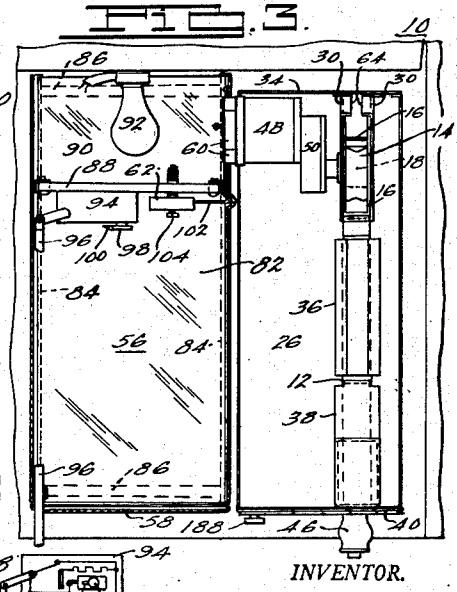
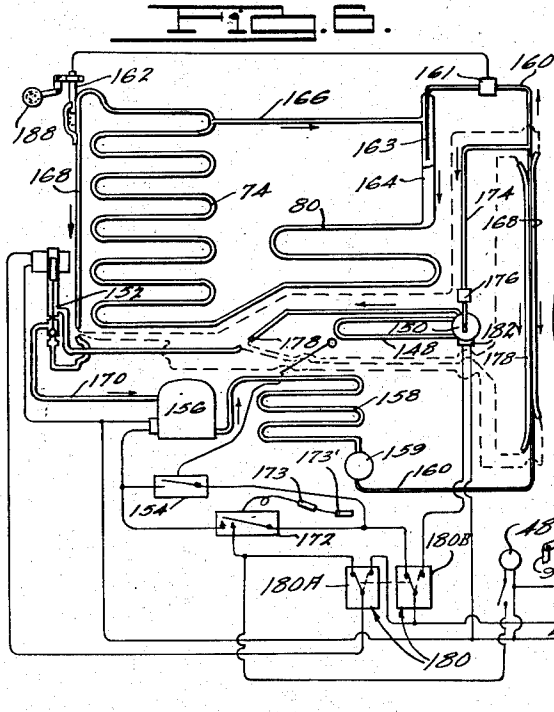


FIG. 5.



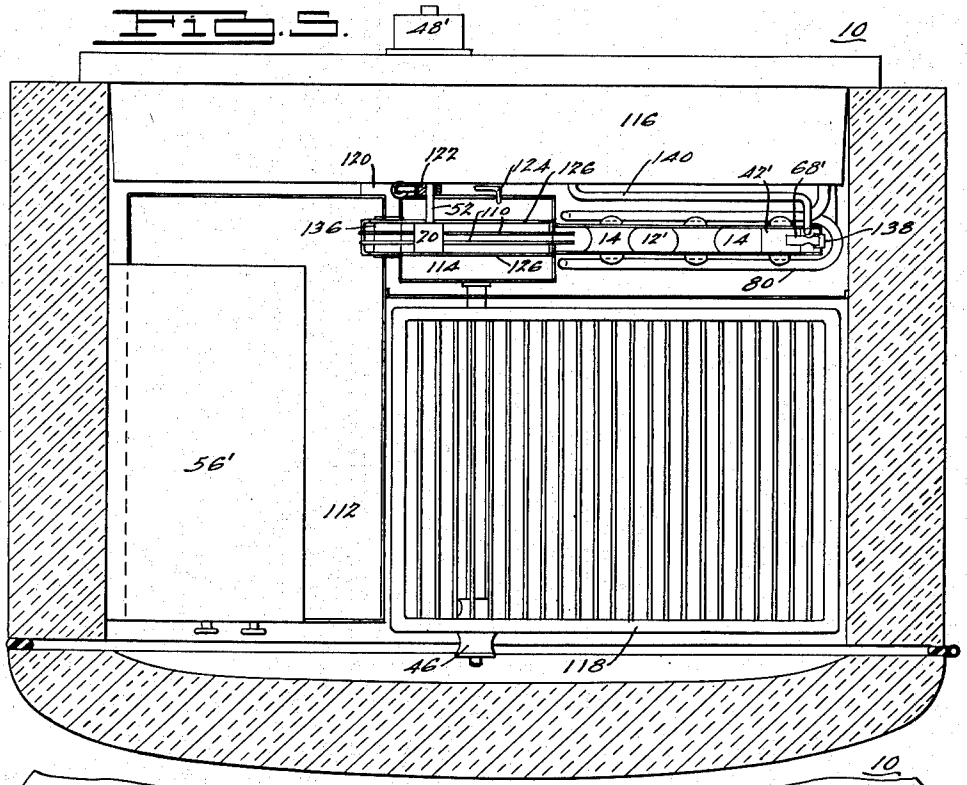
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ICE-MAKING APPARATUS

Filed Nov. 14, 1950 2 Sheets-Sheet 2

FIG. 3.



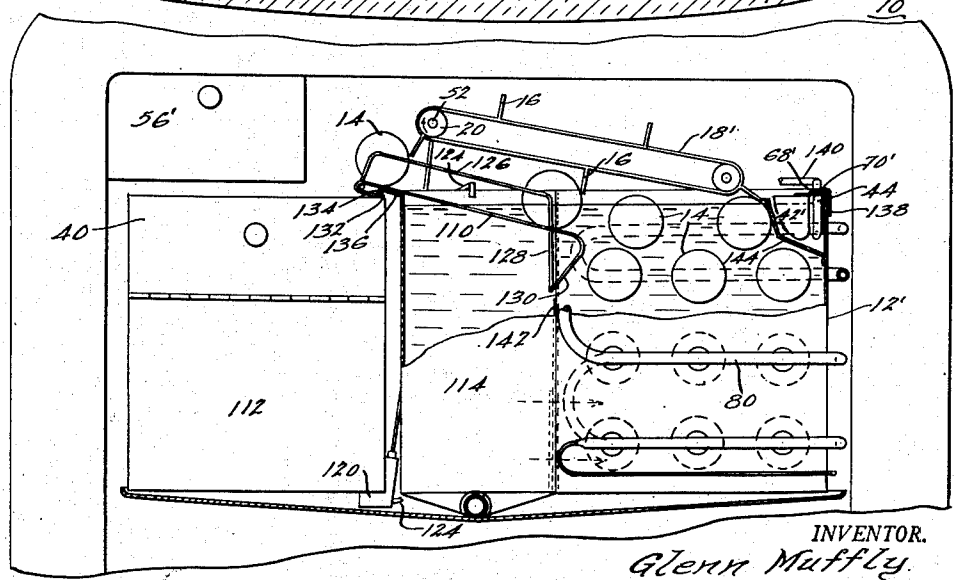


FIG. 4.

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United States Patent Office

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ICE-MAKING APPARATUS

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Application November 14, 1950, Serial No. 195,664

10 Claims. (Cl. 62—4)

This invention is a further development of the ice making apparatus shown in my copending United States application Serial No. 174,944, filed July 20, 1950. That patent application refers in particular to commercial ice making equipment and the present application to an ice maker adapted for use in a household refrigerator of either the compression or absorption type. It is noted, however, that the above mentioned application includes features adapted for use in household refrigerators and the present application will be useful in commerical as well as household refrigerators although here illustrated in connection with a household refrigerator.

Reference is also made to my United States Patents No. 2,145,775, issued January 31, 1939; No. 2,291,826, issued August 4, 1942; and No. 2,359,780, issued October 10, 1944, for earlier disclosures of apparatus for lifting ice from the water in which it has been formed, for storing the ice above the water level and for draining the water of meltage from the ice back to the ice maker tank. Reference is also made to my copending United States applications Serial No. 50,101, filed September 20, 1948, and Serial No. 109,942, filed August 12, 1949, and to my Canadian patent application Serial No. 588,997, filed June 13, 1949.

In some of the above mentioned earlier applications of mine, I have disclosed the use of a water pump to circulate water through the ice maker tank or over the surfaces upon which ice is being frozen. I have also shown the method of floating ice from the tank in which it has been formed, apparatus for mechanically lifting the ice from the tank and the method of pushing a round disk of ice from the tank by means of the head of water accumulated back of it when the ice disk blocks the overflow passage leading from the tank.

One of the objects of the present invention is to eliminate the need for a water pump with its attendant requirement of a packing gland or a vertical drive shaft, and still make clear ice.

Another object is to utilize the elevator which lifts the ice from the water for the additional purpose of agitating the water so as to maintain a constant flow of water over the surfaces of the ice as it forms.

A further object is to reduce the power requirement for agitating the water and lifting the ice.

An additional object is to provide positive means for rolling ice disks into the ice storage compartment instead of employing water flow to float them from the tank in which they are formed or to use a head of water to push them out.

Another object is to provide means for lifting the ice disks from the water in a manner to drain water from them more completely before they drop into the ice bunker.

Still another object is to accomplish the ice lifting and water agitation with a motor requiring an electrical input more nearly balancing the number of B. t. u.'s per hour required to maintain a butter compartment at the optimum temperature when located within the food storage compartment of a household refrigerator.

A still further object is to conserve the space within the refrigerator by a more compact arrangement of parts and by utilizing a part of the space for the dual purpose of storing ice and for storing excess water in the event that all of the stored ice is accidentally melted.

An additional object is to control air temperature within the main food compartment by means of a thermostatic expansion valve mainly responsive to changes of air temperature and thereby to regulate the proportional cooling of the ice maker evaporator and the air cooling evaporator.

Another object is to employ the two evaporators above mentioned as a secondary system which operates during idle periods of the compressor to transfer heat from cabinet air to the ice-maker tank.

A further object is to cause the flow diverting valve to serve the additional purpose of aiding in the defrosting of the freezer evaporator and providing for pressure relief from the evaporator being defrosted.

In the drawings:

Figure 1 is a side elevation of the upper portion of a household refrigerator showing the ice-making apparatus partly in section.

Figure 2 is a front view of Figure 1 showing the same apparatus.

Figure 3 is a horizontal sectional view of Figure 1 or Figure 2 taken on the line 3—3 thereof, omitting the belt.

Figure 4 is a front elevation of the upper portion of a refrigerator showing a modified arrangement in which ice is rolled out of the ice-maker tank and stored in a separate ice bunker.

Figure 5 is a plan view of the apparatus seen in Figure 4.

Figure 6 is a diagrammatic view showing a refrigeration system suitable for use in connection with the previous views.

Referring now to Figure 1, we see that the refrigerator cabinet **10** encloses an ice-maker tank **12** in which ice is frozen by the method disclosed in my previous patents and copending applications and particularly shown in my United States application Serial No. 174,944 wherein two disks of ice separately started are caused to freeze together to make a thicker disk which is then released to float and is pushed from the tank by the head of water back of it. In the present Figure 1, it will be seen that the ice disks **14** are engaged by the vanes **16** which are attached to or formed integrally with the belt **18**. This belt is driven by a pulley **20** and runs over the idler pulley **22** which is located adjacent to the normal operating water level **24** in the tank **12**. The belt passes through the wider upper tank **26** in a space **28** provided in the rear portion thereof and divided from the main tank **26** by means of the walls **30** and **32**. The rear end wall **34** of the ice-maker tank **12** is joined with the rear wall of the upper tank **26** in the same plane so that these rear walls form one continuous surface which prevents the ice disks **14** from rolling off of the vanes **16** as the belt **18** carries them upwardly to the position of the ice disk **14'** which is about to roll off of the belt into the ice bunker formed by the upper tank **26**.

The pulley **20** is driven at a suitable speed to drive the belt at such linear velocity that the vanes **16** enter and leave the water in the ice-maker tank **12** without objectional splashing or noise and yet fast enough to produce a substantial circulation of water within the ice-maker tank **12** in a counter-clockwise direction as viewed in Figure 1. This circulation of water washes air bubbles from the surfaces of ice disks **14** in process of formation and also carries any floating ice disks to the left as viewed in Figure 1 so they come into engagement with the vanes **16** of the belt **18** and are finally lifted by this belt to be deposited in the ice bunker **26**. The vanes **16** are preferably solid paddles and their width is nearly as great as that of the ice maker tank **12** so that they produce the maximum movement of water. Assuming the ice disks to be one inch thick, the width of the vanes **16** will be only slightly less than one inch while their length measured radially from one of the pulleys as the vane passes over it is preferably such as to extend from the belt a distance somewhat greater than one-half the diameter of an ice disk. Since the vertical channel formed by the two side walls **30**, the wall **34** and the belt is only slightly wider than the thickness of the ice disks, they cannot fall off of the vanes **16** during their upward travel. The ice disks must, however, fall off of the belt as it passes over the upper pulley **20** and they can only fall into the ice bunker **26**.

Screens, gratings, or removable sheets **36** and **38** separate the upper tank **26** and the lower tank **12**. This pre-

vents ice disks from returning to the ice-maker tank from the ice bunker and also provides that any water of meltage from ice stored in the bunker will flow back to the ice-maker tank **12**.

One of the important features of this invention is the fact that the ice bunker **26** is located above the ice-making tank and provided with vertical walls which are joined in a water-tight manner to the top of the ice-maker tank, while the access door **40** is located at the upper front portion of the tank, allowing the water-tight front wall of tank **26** to extend upwardly to the opening closed by this door. This provides a water-tight compartment extending upwardly from the ice-making tank **12** and having sufficient internal volume to hold more water than would be obtained by melting the maximum supply of ice that can be stored in the bunker **26**. This provides against flooding the refrigerator and the floor of the room in which it is located in the event of accidental stoppage such as might be caused by failure of electrical current or of a vital part of the refrigeration system.

In the event that such a failure occurs and operation is re-established while the upper tank contains the water of meltage, no harm will result and the first ice disks formed will fall into the water which now fills the lower portion of the ice bunker. The first of this ice will melt to aid in cooling the water, but as ice begins to accumulate in the bunker, the water level will drop until it will eventually stabilize at the normal water level **24** within the ice-maker tank **12**. Assuming now that some of the ice is removed from the bunker and the ice maker continues to operate, using up some of the water in the tank **12** by converting it into ice, the water level **24** will fall and with it the float **42** which causes the water inlet valve **44** to open and restore the operating level to the line **24**. The same replenishment of water within the tank **12** occurs when water is drawn from the faucet **46**.

Figure 2 shows a front view of Figure 1, including the motor **48** and its speed reduction gearing **50** which drives the shaft **52** upon which the driving pulley **20** is mounted. Due to the light load imposed by the pulleys and belt plus the occasional lifting of an ice disk and the fact that the gearing **50** provides a considerable ratio of speed reduction, the motor **48** can be quite small, preferably consuming not over 10 watts and, therefore, it is permissible to locate this motor within the refrigerated space. Some of the waste heat from the motor **48** may be utilized in maintaining the temperature of the butter compartment, as will later be explained.

In Figure 2, it is seen that the lower left corner of the upper tank **26** is rounded and that the bottom of the tank slants downward to the left side of the ice maker tank **12**. This provides for conducting the moisture which condenses on the side and bottom of the ice bunker over to a side wall of the ice-maker tank from which it drops into the pan **54** which, therefore, can be made narrower than would be otherwise required. This pan is preferably drained to the rear corner of the liner of the food space and the water conducted outside of the refrigerated space to be re-evaporated to room atmosphere as disclosed in my copending patent application Serial No. 178,498, filed August 9, 1950.

Referring now to Figure 3, we are looking down on the top of the ice bunker **26**. The butter compartment **56** is located beside and preferably separated from the ice bunker **26**. At its front, it is provided with a door **58** for access and at its rear is provided with a thermostatically controlled shutter **60** which opens in response to a drop of temperature within the butter compartment to allow warm air and radiant heat from the motor **48** to enter the butter compartment for the purpose of maintaining its temperature. As the butter compartment rises to the desired temperature, the thermostat **62** moves the shutter in a closing direction to reduce the heat input to the butter compartment.

The belt **18** and the vanes **16** may be molded or vulcanized together in one piece using a combination of material or one rubber-like material. It is preferred that the vanes **16** be flexible or flexibly mounted upon the belt so as to prevent damage in the event that an extra large disk of ice wedges between a vane and the rear wall **34** of the ice-maker tank in the position indicated in Figure 1 by the ice disk **14″**.

At the top of the rear wall **34** or on the sides **30** of the vertical chute **28** a curved shield **64** is provided as an extension of one or two walls to prevent the ice disks from rolling off from the ends of the vanes **16** as they approach their top position. The vane then pushes the ice disk off the top of the pulley with sufficient force to carry it over the wall **32** into the ice bunker. In the event that an ice disk should lodge between the belt and the top edge of the wall **32**, as indicated by **14‴** in Figure 1, the vane **16** which carried the ice disk up will push the ice disk over the top of the wall **32** so that it falls into the ice bunker.

In order to make the float valve **44** readily accessible, I prefer to use a two-piece cover for the ice-maker tank **12**, as shown in Figure 1. The shield **36** fits into the tank **12** and provides an angular wall **66** which aids in guiding ice toward the elevator. This shield is readily removable by merely lifting it out after removing ice from the bunker **26**. Upon removal of the shield **36** the somewhat similar float cover **38** may be removed by sliding it rearwardly, tilting and lifting it out along with the float **42**, its lever arm **68** and its pivot pin **70**. This provides access to the valve **44** which is preferably threaded into a fitting such as **72** and is readily removable therefrom by the use of a socket wrench. The valve **44** is similar to an automobile tire valve, having a removable core or "valve guts." Such valves are well-known as "tank valves" and are commonly provided with ⅛″ male pipe threads.

In Figure 2, the evaporator **74** is provided with fins **76** and is open to circulation of air from the food storage space of the refrigerator for the purpose of cooling the same. The arrows indicate such circulation and the upper one indicates flow of air into the top of the finned evaporator **74**, there being an opening or openings provided in the sheet metal wall **78** for that purpose. The evaporator **74** may be operated intermittently during periods when the ice maker evaporator is idle, the two evaporators may operate at the same time or they may each operate under its own control as required to make ice and to maintain the desired temperature of cabinet air.

It will be obvious that a considerable amount of cooling of cabinet air is obtained by normal gravity circulation of air over the exposed surfaces of the ice-maker tank **12** and the ice bunker **26** as well as by contact of the ice-maker evaporator **80** during both its active and defrosting periods which are controlled to regulate the size of ice disks made. The controls described later herein and illustrated by Figure 6 provide for so proportioning this operation of evaporators **74** and **80** that cabinet air temperature is maintained within the desired limits and ice production is regulated to maintain the desired supply in the bunker **26**.

The butter compartment **56** is provided with a glass bottom **82** supported by the two side members **84** which are tied together by two or more cross members such as **86**. This compartment is closed at the front by the door **58** and at the rear abuts the rear liner of the cabinet, so that no rear wall is required. There is, however, a partial dividing wall **88** arranged to separate the butter compartment **56** from the rear compartment **90** in which is located the lamp **92**. This wall stops short of the top and bottom of the butter compartment so that the heat produced by the lamp causes warm air to flow forwardly over the partition member **88** and to return below it. In conventional refrigerators it has been customary to provide such a lamp with a switch arranged to close when the refrigerator door is opened. Such a switch is located within the housing **94** and actuated by the push rod **96** which extends forward so that the switch is opened whenever the door is closed. In addition to this switch, I propose to use a second switch connected in parallel with it and enclosed in the same housing **94**. This second switch is of the thermostatic type and arranged to close in response to a drop of air temperature within the compartment **56** and to re-open in response to a rise of this temperature. Such switches have previously been employed to actuate heating elements for the purpose of maintaining the desired temperature in a butter compartment of a refrigerator, but in this case, I propose to use the lamp **92** as a heating element as well as for the purpose of illumination. In order that the thermostatic switch need not carry a heavy current, I propose to include a resistance coil in series with this thermostatic switch and the lamp, so that when the lamp is lighted for the purpose of producing heat,

it operates at a lower-than-normal voltage, hence produces little light but a high percentage of heat in proportion to the amount of light. The resistance element thus connected also provides heat for the butter compartment **56** and acts to hasten the operation of the thermostatic switch which is enclosed in the same housing with it, thus resulting in the effect of an anticipating thermostat. The thermostatic switch within **94** is adjustable from the inside of the butter compartment by means of the knob **98** which carries a pointer **100** to indicate its position.

Another method of supplying heat to the butter compartment is illustrated in Figures 2 and 3, where the bimetal thermostat **62** actuates the connecting rod **102** and thereby the louver vanes **60**. These vanes move to the open position as shown in Figure 2 when the bimetal element **62** drops to the minimum temperature desired within the butter compartment, thus allowing heat from the motor **48** to be transferred by radiation and convection to the compartment **90** and thence to the butter compartment **56** by convection. The thermostat **62** is adjustable by means of the pointer **104**. It will be seen that I have provided three sources of heat for the butter compartment **56**, but it is not proposed that all three be used in the same model. Normally, there will be two sources of heat used such as the lamp and the resistance coil, or the lamp and the heat from the motor **48**, hence there will be only one thermostat employed and only one dial for its adjustment.

When the lamp is connected in series with the resistance coil, it is periodically energized even when the door of the refrigerator is closed. This aids in keeping the lamp base, its electrical connections, and the thermostatic switch dry. It will be noted that the position of the lamp within a somewhat warmer compartment prevents the collection of dew on the lamp and its base as well as on the connecting wires and the operating switch. The lamp's location above the glass **82** protects it and avoids the usual interference with the cleaning of the refrigerator's interior.

It is also within the scope of my invention to keep the lamp in the position shown and connect it only with the door-operated switch so that it operates in the usual manner, but it and its switch are enclosed within this warmer compartment where both are readily accessible for service and less servicing is required because both are kept dry. In this case the thermostatic switch adjusted by the knob **98** would be independent of the lamp circuit and in series only with the resistance coil which provides all of the heat for the butter compartment except the incidental heat from the lamp **92**, which is produced only while the refrigerator door is open.

Another arrangement is to keep the lamp and its switch independent as above described, eliminating the knob **98**, its switch and the resistance coil but using the thermostatically controlled shutter whereby heat is admitted to the compartment **90** from the motor **48**. This retains the dry location of the lamp and its switch and provides the additional heat without use of electrical current by merely opening the louvers **60** when required to maintain the desired temperature within the butter compartment.

The lamp bulb may be removed by sliding the glass **82** forward and whatever switch or thermostat is used can be readily removed for servicing along with the supporting wall **88**, which is preferably made of thermal insulating material.

Figure 4 shows a modified form of the apparatus seen in the first three figures, differing mainly in the arrangement of parts. The elevator belt **18'** is arranged at an angle instead of vertically so that the round ice blocks **14** are caused to roll up the inclined track formed by the wires **110** instead of being lifted vertically as shown in Figure 1. This elevator delivers the blocks of ice to the ice bunker **112** which is separate from the ice-maker tank instead of being an upward extension of it as shown in Figures 1 and 2. The motor **48'**, which includes gear reduction to drive the belt **18'** of Figure 4, is located outside the refrigerated space as shown in Figure 5 instead of being located inside of the refrigerated space as shown in Figures 2 and 3. The butter compartment **56'** is therefore heated by an electrical resistance element under thermostatic control as described in connection with the control assembly **94** of Figures 2 and 3, though this motor could optionally be located inside the refrigerated space adjacent to the butter compartment **56'** for the purpose of heating it if desired.

The ice-maker tank **12'** is joined at its left end with the water tank **114** and the faucet **46** is connected with this water tank instead of being located on one end of the ice-maker tank. The ice-maker tank is located adjacent to and parallel with the inner side of the removable plug **116** back of the shelf **118** which is provided for the storage of tall bottles whereas in the arrangement of Figures 1, 2 and 3 such bottles would be placed on the shelf **118'** at the left side of the ice-making apparatus.

Since the ice storage bunker **112** of Figure 4 is located at the same level as the ice-maker tank instead of above it as shown in Figures 1 and 2, provision is made for disposal of the water of meltage. This is done by means of the pump **120** which may be of a reciprocating type driven by an eccentric **122** (Fig. 5) on the shaft **52** which carries the pulley **20** and drives the belt **18'**. Water resulting from ice meltage is returned to tank **12'** or **114** by means of the tube **124**. The ice bunker is provided with a water-tight front ot which the door is hinged at one-half to two-thirds of the height of the ice bunker. This provides storage space for the water resulting from ice meltage in the event of current failure or accidental stoppage of the refrigerating system. In Figures 4 and 5, the water in the ice-maker tank is stirred by the vanes **16** of the belt as previously explained in connection with Figure 1. The belt is not, however, required to lift the ice disks from the water but merely to roll them up on the ramp formed by the wires **110** under guidance of the side wires **126**. These wires may all be formed by one continuous wire which also forms two vertical portions **128** and two angular legs **130** which hold the formed wire element in position and guide the ice disks upwardly into the path of the vanes **16** after the ice is released from the walls of the tank. The two ends of the formed wire are bent upwardly at **132** to be retained back of the downwardly extending lip **134** of the spout-like extension **136** of the tank **114**. Assembly of the wire element to the tank is acomplished by hooking the ends **132** back of the lip **134** and then swinging the wire member downwardly through the adjacent corner of the ice-maker tank until the vertical legs **128** snap into position as shown in Figure 4. Removal is accomplished by squeezing the two legs **128** together so that the wire will again pass through the corner of the ice-maker tank.

The float **42'** is pivoted at **70'** to the inverted U-shaped member **138** which fits snugly over the end of the ice-maker tank so that when the float **42'** falls as a result of a drop of water level in the ice-maker tank the arm **68'** contacts the stem of the valve **44** to admit additional water from the supply tube **140**. A wall member **142**, which is preferably removable, is provided to prevent any pieces of ice from floating into the water tank **114**. Ice disks are free to float upward when released since the ice-maker tank **12'** is slightly wider at its top than at its bottom as is the similar tank **12** seen in Figure 2. This ice may float directly into the path of the vanes **16** of the belt **18'** or they may be guided into such contact by the angular wire legs **130** or by the shield **144** which protects the float **42'**.

In Figures 4 and 5 as well as in Figures 1, 2 and 3, the floating disks of ice are lifted from the water mechanically rather than being floated out as in my copending application, Serial No. 50,101 filed September 20, 1948 or rolled out by a head of water accumulated back of an ice disk as shown in my copending application, Serial No. 174,944 filed July 20, 1950. This eliminates the necessity for pumping overflow water back to the ice-maker tank. The pulley **20** which drives the belt **18** or **18'** could be driven at an extremely slow speed and still move the belt rapidly enough to remove the ice blocks as fast as they are released, but it is proposed to drive this pulley at a somewhat higher speed so that the vanes **16** will produce sufficient agitation of the water in the ice-maker tank to wash air bubbles from the surfaces of the ice disks as they are forming and thus insure the production of clear ice. Since water is not being pumped through restricted passages nor lifted to produce agitation and the motor shaft requires no packing gland, the motor which drives the belt **18** or **18'** can be considerably smaller than the motor required to operate a pump which produces enough flow

to wash the air bubbles from the ice and to cause the ice to float out of the tank in which it is made.

Figure 6 shows diagrammatically a system suitable for use in connection with the previous views and including a freezer evaporator **148** which is employed to cool a frozen food compartment as is the evaporator **20** of my copending United States Patent Application Serial No. 74,528 filed February 24, 1949, or evaporator **88** of my copending United States patent application Serial No. 178,498 filed August 9, 1950. This evaporator includes a header **150** and is selectively cooled under control of solenoid valve **152** and thermostatic switch **154** which responds to temperature changes of a bulb located adjacent to evaporator **148**.

The solenoid of valve **152** is energized while motor-compressor unit operates to cool evaporators **80** and **74**. During this period refrigerant vapor compressed by the motor-compressor unit **156** is delivered to the condenser **158** and liquid accumulating therein flows into the receiver **159** and thence through the tube **160** to the expansion valve **161** which is of the thermostatic type and has its bulb **162** adjustedly supported, as will be explained later.

Liquid refrigerant leaves the expansion valve **161** through the tube **163** which extends into the tube **164** past the point at which tube **164** is joined by tube **166**. This produces a jet effect which induces flow through the tube **166** in the direction indicated by the arrow. A portion of the liquid refrigerant evaporates in the evaporator **80**, seen in previous figures as part of the ice maker.

Vapor and unevaporated liquid refrigerant flow from the evaporator **80** into the evaporator **74**, which is arranged to cool air within the refrigerator cabinet and is preferably provided with extended surface as shown in Figure 2. Refrigerant vapor leaves evaporator **74** through the tube **168** while any unevaporated liquid refrigerant reaching the top of evaporator **74** flows through the tube **166** into the tube **164** and recirculates until evaporated. At the time evaporators **80** and **74** are active the solenoid valve **152** is lifted so that refrigerant vapor flows from the tube **168** into the main suction tube **170**, which leads back into the low pressure casing of the motor-compressor unit **156**.

This cycle of operation is under control of the thermostatic switch **172** which when closed energizes the motor of the unit **156** and also closes the circuit through the solenoid of valve **152** which causes the armature of the solenoid to lift the valve so that tube **168** is open to tube **170**. When only the thermostatic switch **154** is closed as a result of a rise of temperature in the freezer compartment cooled by the evaporator **148**, the motor-compressor unit **156** is likewise energized, but there is no flow of current through the solenoid of valve **152**, hence the outlet of tube **168** is closed and enough pressure will have built up in the evaporators **74** and **80** to close the expansion valve **161**. Liquid refrigerant therefore flows from the tube **160** through the branch liquid tube **174** to the expansion valve **176**, which feeds the freezer evaporator **148**. Vaporized refrigerant leaves the evaporator **148** through the suction tube **178** which connects with the header **150** and is now open at the valve **152** for the flow of refrigerant vapor from the tube **178** to the main suction tube **170** and thence back to the unit **156**.

In the event that thermostatic switch **172** recloses before the switch **154** reopens, the cooling effect will shift back to the evaporators **80** and **74**, due to the energizing of the solenoid and consequent lifting of the valve member of **152**. The main food compartment of the refrigerator is thus cooled and ice is formed until the switch **172** reopens, whereupon cooling of the evaporator **148** continues until the freezer air temperature falls to the cut-out point of the switch **154**, whereupon the unit **156** stops.

An additional switch **180** is provided for defrosting of the evaporator **148**. This may be a double pole, double throw switch, which for convenience and clarity is here shown as **180A** and **180B**, with the two blades or movable members shown in solid lines and their alternative positions shown by dotted lines. As indicated by solid lines the switch **180** is in its normal position which prevails at all times except when the heating element **182** is to be energized for the purpose of defrosting the freezer evaporator **148**.

It will be seen that when the two blades of the switch **180** are simultaneously moved to their dotted positions the blade of **180A** connects one side of the line with one pole of the solenoid while the blade of **180B** connects the same side of the line with a terminal of the heating element **182**. Since the opposite poles of these two electrical coils are permanently connected with the other side of the line, actuation of the switch **180** to move its movable contact elements to the positions shown by dotted lines will complete the circuits through the solenoid of **152** and through the heating coil of **182**. This causes the valve of **152** to lift, closing the outlet of tube **178** while at the same time the heater **182** causes evaporation of liquid refrigerant in the header **150** of evaporator **148**. Such evaporation of refrigerant causes condensation of refrigerant vapor within the tubes or passages of the evaporator **148** and within the upper portion of the header **150**, thus melting any frost or ice that may have accumulated on these parts or extended surfaces thereof.

The outlet of tube **178** is stopped by a valve held closed magnetically, hence this valve acts as a pressure relief valve. In the event of excessive pressure developing within the evaporator **148** refrigerant vapor is allowed to pass into the tube **170** and thence to the low pressure side of the unit **156**, which has ample internal volume to receive and hold all of the refrigerant vapor that may be passed by the valve **152** during the defrosting of evaporator **148**.

The switch **180** may be actuated either manually or automatically, but it is preferred that at least the termination of the defrosting operation be automatic, as disclosed in my copending patent application Serial No. 178,498 above mentioned, which discloses means for accomplishing automatic starting as well as stopping of the defrosting operation.

Figure 6 also shows connections for supplying electrical energy to the motor **48** and to the lamp switch and butter compartment heater **94** which are seen in Figures 2 and 3. It will be noted that the thermostatic switch **172** is shown with two bulbs instead of the usual single bulb. One of these bulbs is adjustably located adjacent to an ice making area and the other is located so as to be responsive to changes in the quantity of ice in storage under the additional influence of changes in air temperature within the refrigerator, as disclosed in my copending application, Serial No. 178,498 and illustrated by bulb positions in Figure 6 thereof. This arrangement causes the switch **172** to regulate the ice making cycles to produce ice disks of the desired size and to maintain the desired quantity of ice in storage, this quantity of ice being greater when the air temperature of the main food compartment of the refrigerator is near its high limit than when the air temperature is near its low limit.

In addition to this previously disclosed method of control, the present invention provides additional means for proportioning the cooling effects produced by the ice maker evaporator **80** and the cabinet air cooling evaporator **74**. The expansion valve **161**, being of the thermostatic type, is urged in its closing direction by a reduction of temperature of the bulb **162**. In the event that the bulb **162** is at a higher-than-normal temperature, the expansion valve **161** maintains a higher-than-normal operating pressure within the evaporators **80** and **74**. It will be noted that the bulb **162** is associated with the outlet of evaporator **74**, but also has a considerable portion of its length exposed to air temperatures above its contact with the tube **168**. The bulb is adjustably supported so that more or less of its length can be exposed to cabinet air temperature. An upward adjustment of the bulb may raise the liquid level within the bulb above the uppermost contact between the bulb and its support or with the tube **168**.

This provides for increasing the flow of liquid refrigerant through the expansion valve **161** when the air temperature within the refrigerator is higher than normal. This increased flow of liquid causes evaporator **80** to operate at a higher-than-normal evaporating temperature, thus slowing down the formation of ice. At the same time the greater supply of liquid causes more of the evaporator **74** to be cooled and this cooling is prolonged due to the slower formation of ice and consequent longer running period for each batch of ice frozen.

While the bulb **162** is closely enough associated with the tube **168** to insure against frost-back, the expansion valve **161** is set at a considerably higher superheat than is customary in thermostatic expansion valves, thus the expansion valve **161** is controlled mainly by air temperature and only in emergency by suction tube temperature to prevent frost-back. The result is that evaporator **74**

may have only its lower loops frosted during normal operation of the refrigerator, but in the event of frequent door openings, an excessively high ambient temperature, or the placing of an unusual amount of warm food in the main food compartment of the refrigerator, the evaporator **74** will be supplied with more liquid and be frosted nearly to its top. Since the length of each running period depends upon the formation of ice and the evaporator **80** is under this condition operating at a higher pressure than usual, the formation of ice is retarded and the running period prolonged while the evaporator **74** presents a greater cooled area to the cabinet air.

During idle periods of the system, that is when the motor-compressor unit **156** is idle, and when the system is actively cooling the freezer evaporator **148**, the evaporators **74** and **80** are isolated from the balance of the system by the valve **152**, which closes the outlet of tube **168**, and by the expansion valve **161**, which does not allow flow in a reverse direction. There will always be some liquid refrigerant trapped within these two evaporators at the time the switch **172** opens and the solenoid is thereby de-energized. The cross-over tube **166** allows vapor from the evaporator **74** to flow into the upper portion of the evaporator **80** where it will condense due to the fact that evaporator **80** is in intimate thermal contact with the ice-maker tank **12** while the evaporator **74** is not only in air but is provided with fins, as seen in Figure 2, so that it approaches more closely to cabinet air temperature, causing liquid refrigerant to evaporate in **74** under the same pressure at which it condenses in the evaporator **80**, which now acts as the condenser of a "secondary" or constant pressure refrigerating system, transferring heat from cabinet air to the ice-maker tank **12**.

Figure 6 illustrates the method of controlling cabinet air temperature in the main food space, which must be held above the freezing point and is preferably held below 40° F. A considerable part of the cooling effect required is obtained by air contact with external surface of the ice bunker **26**, the ice-maker tank **12** and the ice-maker evaporator **80**, but a variable amount of additional cooling effect is required to hold the air temperature within the main food storage space below the desired top limit which may be 40° F. or lower. This variable cooling effect is supplied by the evaporator **74**. This evaporator does some cooling of air each time the ice-maker evaporator **80** is cooled for the purpose of making ice.

Evaporator **80** is under control of thermostatic switch **172** which has two bulbs **173** and **173'** connected with it, bulb **173** being located relative to an ice-making area and bulb **173'** relative to the height of the maximum ice supply in the storage compartment **26**. Equivalent locations of the two bulbs connected with one thermostatic switch are shown at **44** and **138** in Figure 6 of my copending U. S. patent application Serial No. 178,498 filed August 9, 1950. Bulb **173** regulates ice-making periods by stopping the compressor when a given piece of ice has grown to the desired size and by starting the compressor when the ice has melted free from the surface on which it was frozen and floated. Bulb **173'** which is located in the ice bunker, takes no part in the control until the ice supply has accumulated to slightly above the level of the bulb, thus cooling bulb **173'** and causing the liquid portion of the volatile charge of the thermostatic switch **172** to collect in this bulb, which is now colder than bulb **173** associated with the ice-making area.

Each of these bulbs is affected to some extent by a rise of cabinet air temperature, in the direction of hastening the starting of an ice-making cycle and increasing running time, which effect tends to cause more cooling of cabinet air when the cabinet air temperature is higher than normal, but I have in the present application shown additional means for control of cabinet air temperature. This control is accomplished by further modification of the ice-making cycles and by varying the amount of cooling done by the finned evaporator **74**. It will be obvious that when evaporator **80** is cooled to a very low temperature and a relatively small amount of liquid refrigerant is allowed to flow into evaporator **74** ice will be formed rapidly and the evaporator **74** will do only a small amount of cooling of cabinet air. On the other hand when evaporator **80** is operated at a higher temperature, with a greater excess of liquid refrigerant flowing from it into evaporator **74**, more time will be required in forming ice disks of the desired size and during this longer period of operation a larger portion of the evaporator **74** will be actively cooled by the evaporation of refrigerant.

In order to regulate the removal of heat from cabinet air I employ the thermostatic expansion valve **161**, which is responsive to variations of low side pressure and also to variations in temperature of the bulb **162**. Such bulbs are commonly placed in heat exchange relationship with the outlet of an evaporator and the valve is designed to maintain approximately the desired temperature at the evaporator outlet. It is common practice to identify the setting of such valves in terms of "superheat" of refrigerant vapor at the point of bulb attachment to the evaporator outlet tube. They are used to insure cooling of substantially the entire evaporator from start to finish of its active period. In the present case the bulb **162** has only a slight contact with the tube **168** leading from evaporator **74** but has a considerable portion of its area exposed to the circulation of warm air approaching the top of the fins **76** of evaporator **74**.

In addition I make the valve **161** responsive to temperature changes of bulb **162** at higher temperatures than usual. In other words, the valve **161** is set at a much higher "superheat" than usual. When the bulb **162** is cooled to say 35° F. the evaporator **80** may be operating at 10° F. with substantially all of the liquid refrigerant evaporating in the evaporator **80** and very little of it in evaporator **74**. This condition would be stated as operating at a "superheat" of 25° F. If the valve really maintained a 25° "superheat" and bulb **162** was increased from a temperature of 35° to a temperature of 40° the evaporating temperature would rise from 10° F. to 15° F., thus slowing down the formation of ice and allowing more liquid refrigerant to flow into the evaporator **74**. I may, however, prefer to design the valve **161** so that the rise of temperature of bulb **162** increases the flow of liquid refrigerant so that evaporator **80** operates at say 20° F. and a still greater proportion of the liquid refrigerant flows into evaporator **74**. In other words, the expansion valve **161** may operate at a diminishing "superheat" as the temperature of its bulb **162** rises. This arrangement of the bulb **162** so as to be mainly responsive to temperature of the warmer cabinet air approaching the top of the fins **76** modifies the cooling of evaporator **74** so that only one or two of its lower loops may be cooled by evaporation of refrigerant when cabinet air temperature is low (say 35° F.) and substantially all of evaporator **74** is cooled when the air temperature rises to say 40° F.

It will be obvious that under the latter condition, the bulb **162** will begin to be cooled by the tube **168** through which colder vapor is now flowing, thus the slight thermal contact between bulb **162** and tube **168** is sufficient to insure against frost-back from evaporator **74**, even though the air temperature may be quite high, as in the case of pulling down a warm cabinet.

In addition to varying the refrigerated area of evaporator **74** to maintain the desired air temperature it will be seen that each running period of the connected evaporators **74** and **80** will be longer when they are operating at a higher evaporating pressure, since this slows down the formation of ice and the running period ends in response to the building up of one of the ice disks **14** to the maximum size established by the location of the bulb of thermostat **172** which contacts the tank **12** adjacent to one of the ice-making areas thereof.

In effect the bulb **162** replaces the usual bulb of a thermostatic switch in the control of cabinet air temperature. When cabinet air temperature is high this bulb causes evaporator **74** to be more fully cooled and to be cooled for longer operating periods, thus pulling the air temperature down to normal for the purpose of holding it within the desired limits. The adjustment of bulb **162** relative to tube **168** to decrease the thermal conductivity between these parts has the effect of a "colder" setting of the ordinary manual adjustment of a thermostat switch which responds to air temperature within the cabinet. The knob **188**, Fig. 2, may be arranged to move bulb **162** for this purpose.

Another effect obtained by the system illustrated in Fig. 6, as applied to any of the other figures and particularly to Figs. 1, 2 and 3, is that in the event of a prolonged idle period, such as might be caused by failure of the source of current, the reserve cooling effect of ice and cold water in the tank **12** becomes effective in cooling cabinet air, not only by exposed surfaces of the tank

and of the evaporator **80**, but by means of evaporator **74** which acts as a secondary evaporator during idle periods of the system with evaporator **80** serving as the secondary condenser. This hold-over effect can be greatly increased by raising the water level **24** so that at least the lower portion of the ice stored in ice bunker **26** is below the water level. While it is true that the water within the tank **12** is normally maintained between 32° F. and 39.2° F., and is consequently within the range of reverse thermal expansion of water, the 32° water in contact with the ice will be more dense than the water in the tank **12** when the latter rises to 40° F. Thus there will be thermal circulation of water in the event of a prolonged idle period such as might result from current failure and this utilizes the stored ice more effectively for the purpose of cabinet air cooling in an emergency.

The motor **48** may be connected across the line to run continuously or it may be connected as shown in Figure 6 so that this motor operates during ice freezing periods only. In the latter case it is assumed that the tank **12** will have ample volume above its ice-making areas for released pieces of ice to float out of contact with such areas or that upon starting of motor **48** ice will be removed rapidly enough to insure against any of the floating pieces of ice being trapped by freezing to the wall areas which evaporator **80** is starting to cool.

Figure 6 also shows the wiring to the assembly **94** which includes a heating element and a thermostatic switch for connecting the heating element of **94** in series with lamp **92** when the temperature of butter compartment **56** falls and opening this circuit when the butter compartment has risen to the desired high limit of temperature. The lamp **92** lights under full line voltage as usual when the door-operated switch is closed, this switch being connected to short out the heating element of **94**.

I claim:

1. In a refrigerator, a refrigerating system for cooling said refrigerator, an evaporator included in said system and arranged to cool air within said refrigerator, a portion of said evaporator near its inlet end being arranged for making ice, a thermostatically controlled expansion valve connected in said system to control the flow of liquid refrigerant to said evaporator, a thermally affected element of said expansion valve being exposed to said air and mainly responsive to temperature changes thereof, and control means responsive to the increase in volume of a body of said ice to control the removal of refrigerant vapor from said evaporator, said expansion valve and control means coacting to cause said evaporator to present more cooled area to said air and be actively cooled by removal of vapor therefrom for longer periods of time when said air temperature is higher.

2. In a refrigerator, a refrigerating system including two evaporators connected in series, the first of said evaporators being adapted for producing sub-freezing temperatures and the second for cooling air within said refrigerator, valve means controlling the flow of liquid refrigerant to the first of said evaporators, and thermally responsive means for controlling the first said means to increase said flow mainly in response to a rise of temperature of the cooled air in said refrigerator, whereby more or less liquid refrigerant is caused to enter and evaporate in said second evaporator and said air temperature is thereby held within preselected limits.

3. In a refrigerator, ice-making means, an evaporator associated with said ice-making means, a thermostatic expansion valve arranged to control the flow of liquid refrigerant to said evaporator, a second evaporator arranged to cool air within said refrigerator and connected in series to receive liquid refrigerant and the vapor thereof from the first said evaporator, said expansion valve having a thermally affected element located in position to respond to changes of air temperature within said refrigerator whereby said evaporators are supplied with an increased flow of liquid refrigerant and caused to operate at higher temperatures when said air temperature is high, and control means responsive to ice formation for controlling the operating periods of said pair of evaporators, said operating periods being thereby prolonged when the evaporators are operating at higher temperatures and ice is therefore being frozen more slowly, said valve regulating flow so that only a part of the second said evaporator is cooled by evaporation of refrigerant during periods of low temperature operation and a greater part of it being so cooled during periods of higher temperature operation, whereby the temperature of said air is maintained within desired limits.

4. A refrigerating system including two evaporators, one of said evaporators being arranged to cool a space in which the air temperature is maintained above 32° F. and the other being adapted for operation at a lower temperature, means forming an outlet passage for each of said evaporators, means forming a main suction passage of said system, valve means arranged to connect said outlet passages one at a time with said main suction passage, heating means associated with said lower temperature evaporator to defrost it by causing refrigerant to evaporate and to condense therein, and control means for simultaneously energizing said heating means and actuating said valve means to close the outlet passage of said lower temperature evaporator, said valve means being so constructed and arranged as to act as a pressure relief valve allowing refrigerant vapor to escape from said lower temperature evaporator into another portion of said system when excessive pressures are developed in said lower temperature evaporator.

5. A refrigerator cabinet including a compartment for the storage of frozen foods and a second compartment adapted to be maintained above 32° F., a refrigeration system including two evaporators, one for each of said compartments, means forming a main suction passage of said system, means forming a separate outlet passage for each of the two said evaporators, valve means arranged to connect said outlet passages one at a time with said main suction passage, and means for defrosting the evaporator which cools said frozen food compartment and simultaneously actuating said valve means to close the outlet passage of the last said evaporator.

6. In a refrigerating system, a pair of evaporators connected in series, a thermostatic expansion valve connected to supply liquid refrigerant to the first of said evaporators, and a control bulb of said valve located adjacent to the second of said evaporators and primarily in heat exchange with cooled air adjacent said evaporator, said bulb being also in adjustable heat exchange with the outlet portion of said second evaporator.

7. A refrigerating system, means for controlling said system to effect cyclic operation of an evaporator thereof whereby a predetermined quantity of ice is formed during each period of active cooling of said evaporator, and means responsive to temperature variations of air cooled by said system to modify the operating temperature of said evaporator, thus controlling the temperature of said air by varying the time required in forming said predetermined quantity of ice and thereby varying the lengths of operating periods of said evaporator.

8. In a refrigerating system, a pair of evaporators connected in series, the second of said evaporators being employed to cool air, a thermostatic expansion valve arranged to feed liquid refrigerant to the first of said evaporators, a thermo-sensitive element of said expansion valve located in heat exchange relationship with the second one of said evaporators and also in heat exchange relationship with circulating air flowing toward said second evaporator, and means for adjusting said heat exchange relationships to increase the heat transfer rate of one and reduce the heat transfer rate of the other with reference to said element.

9. A refrigerating system including a pair of evaporators connected in series, the first of said series of evaporators being employed to freeze separate pieces of ice of which a batch is completed during each operating period of said evaporator, control means for regulating said ice freezing periods, means for causing the second of said evaporators to be variable as to the area thereof which is cooled by evaporation of refrigerant, and control means responsive to temperature changes of air adjacent to said second evaporator for increasing said cooled area in response to a rise of temperature of said air.

10. In a refrigerating system, two evaporators connected in series, a thermostatic expansion valve arranged to feed liquid refrigerant to the first of said evaporators, and a thermally responsive element of said valve so located as to be mainly affected by temperature changes of a fluid which recirculates over and is cooled by the second of said evaporators and secondarily responsive to temperature changes of the outlet end of said second evaporator.

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