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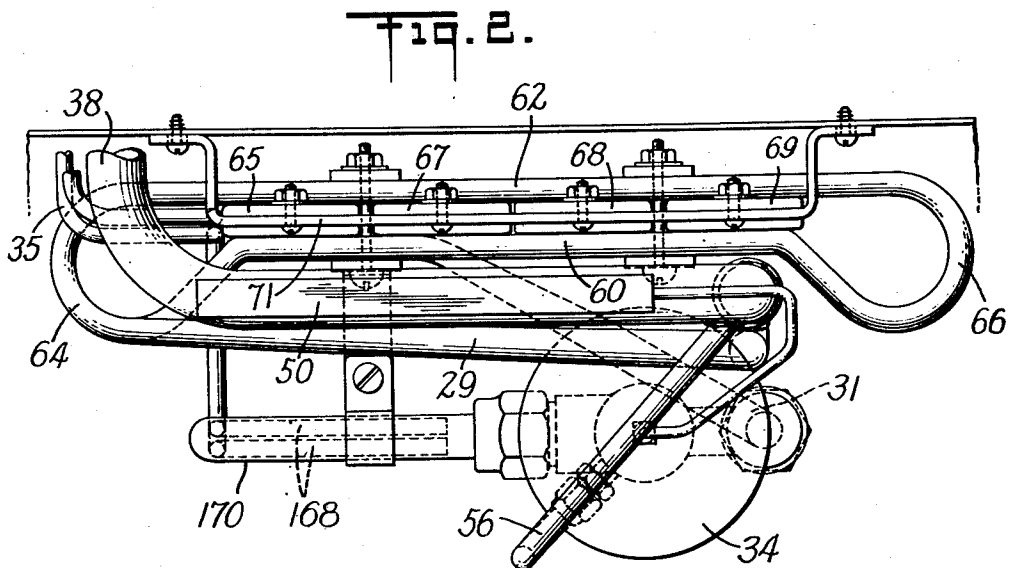
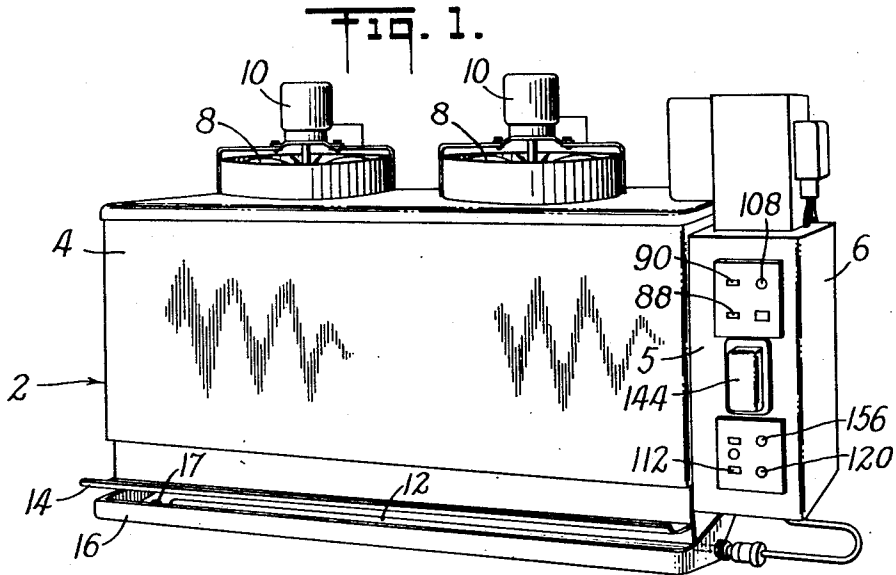
T. W. BINDER

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REFRIGERATION APPARATUS, INCLUDING DEFROSTING MEANS

Filed July 13, 1946

4 Sheets-Sheet 1



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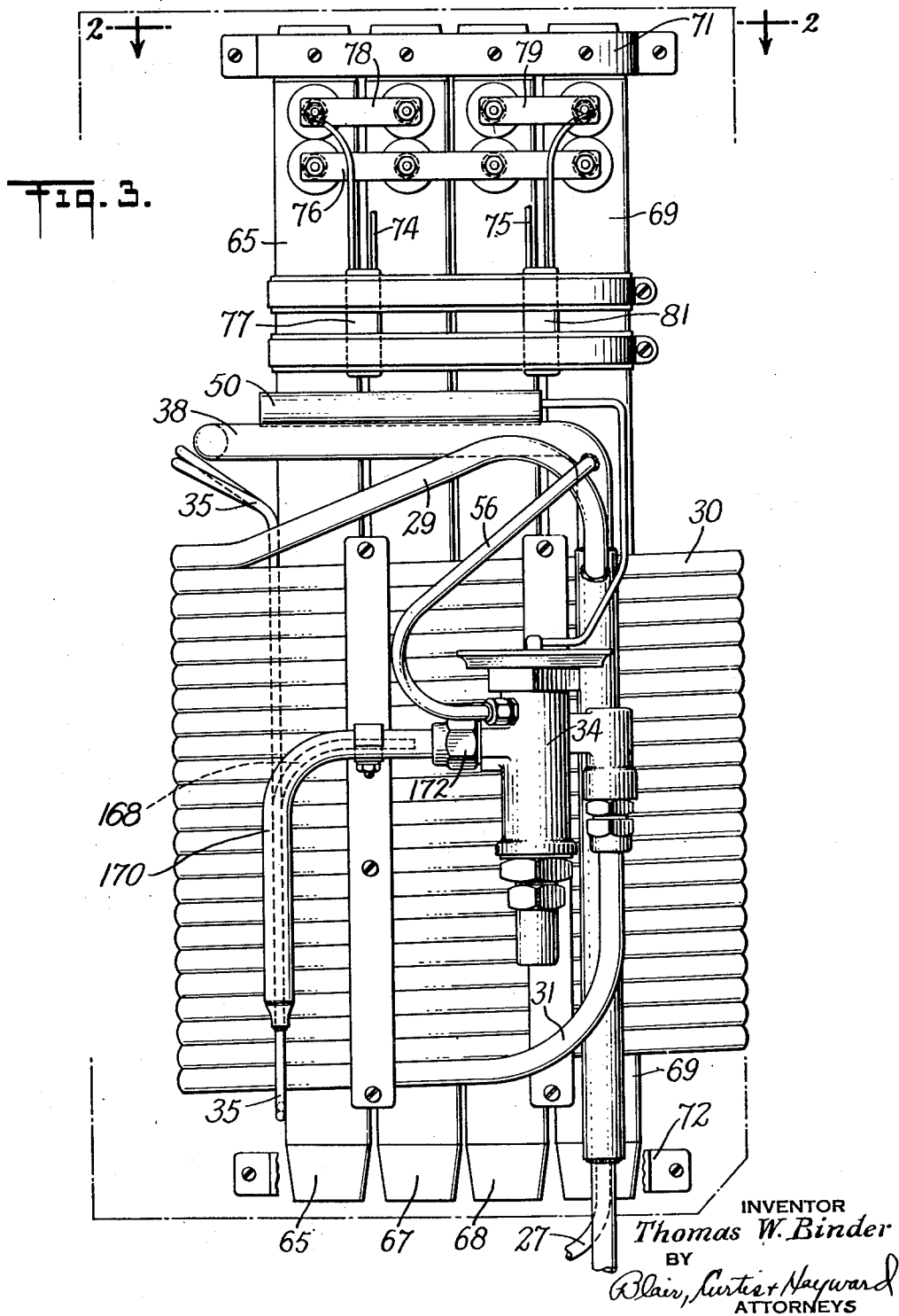
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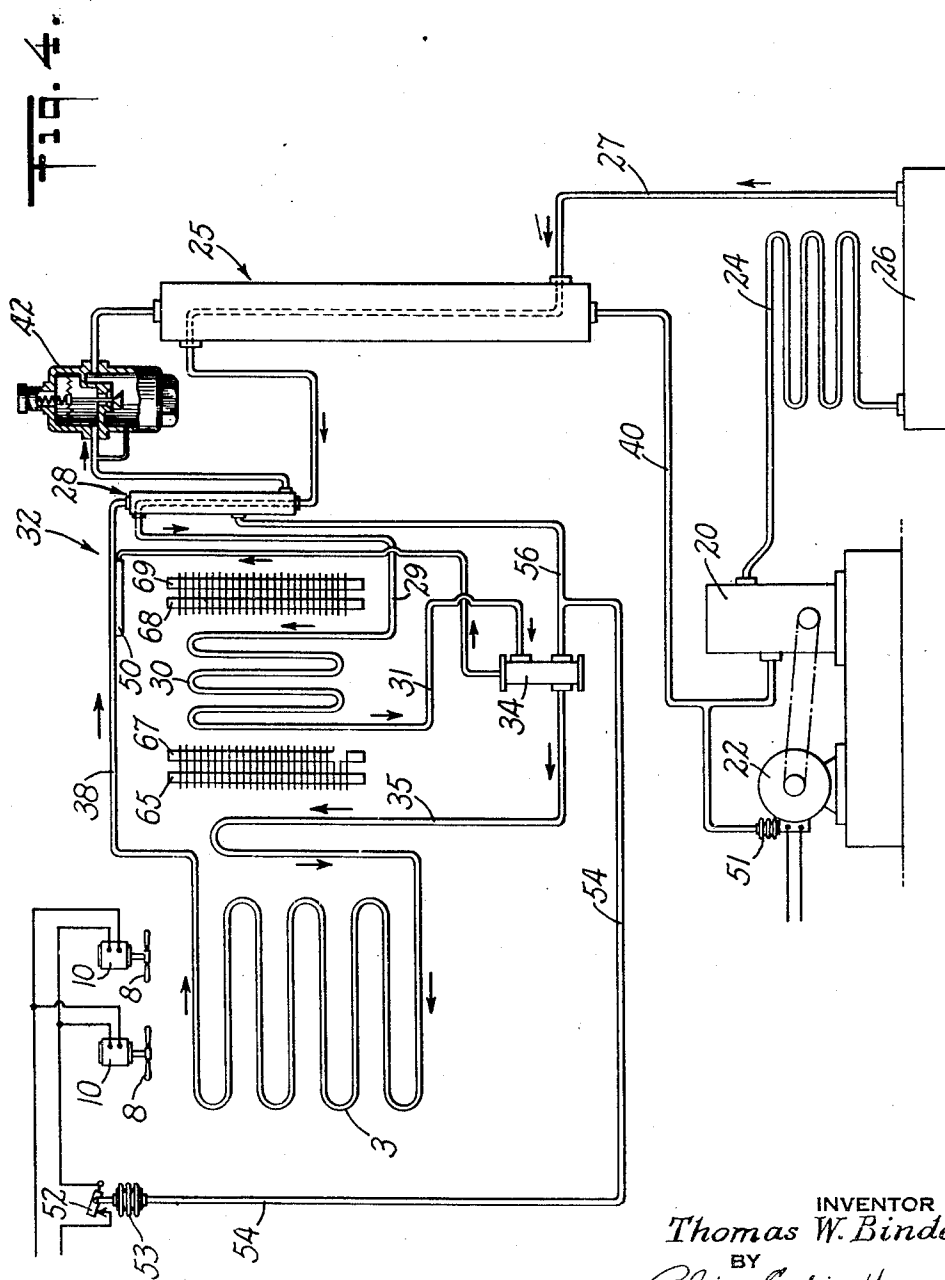
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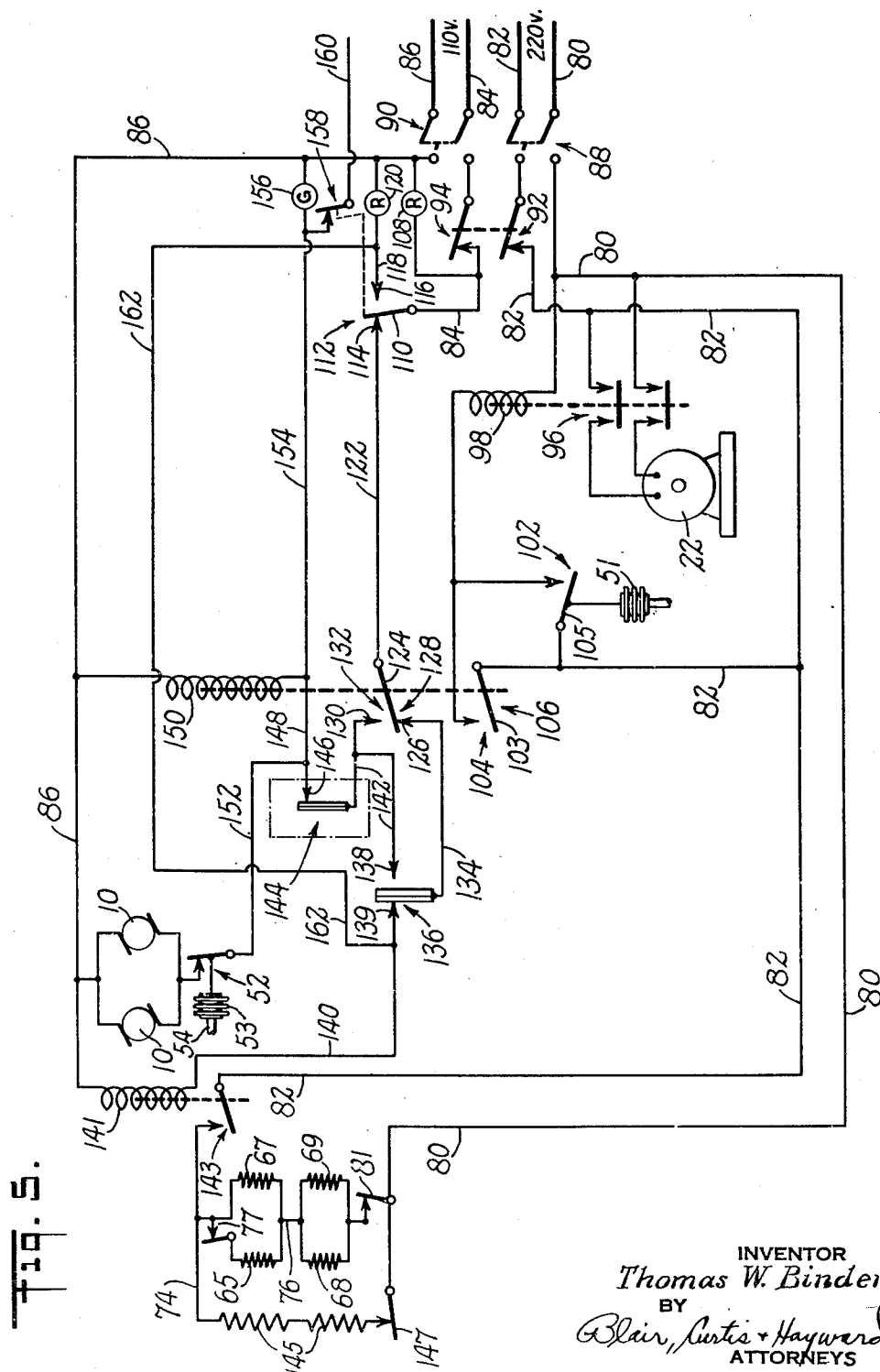
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4 Sheets-Sheet 4



UNITED STATES PATENT OFFICE

2,573,684

REFRIGERATION APPARATUS, INCLUDING
DEFROSTING MEANS

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Application July 13, 1946, Serial No. 683,369

7 Claims. (Cl. 62—3)

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This invention relates to refrigeration, and more in particular to apparatus and a method of operating the same whereby the cooling coil for a low-temperature storage compartment is maintained free of frost (the term "frost" as used herein refers to frost and ice accumulations on the cooling surfaces), and whereby the compartment is maintained within very close limits of the desired temperature.

An object of this invention is to provide in a practical and dependable manner for the defrosting of the cooling element of a refrigeration system. A further object is to provide for automatic or semi-automatic defrosting of a low-temperature refrigeration system. A still further object is to provide a refrigeration system for use in maintaining extremely accurate temperature conditions within a refrigerated space. A still further object is to provide for maintaining the temperature in a frozen food compartment at a temperature such as minus 20° F. with a negligible temperature variation even though there is a tendency to accumulate frost on the cooling surfaces. Another object is to provide a refrigeration system of the above character which is compact and sturdy in construction, and yet which is thoroughly practical and will meet the most exacting requirements during actual use.

In the drawings in which is shown one embodiment of the invention:

Figure 1 is a perspective view of the evaporator unit assembly of an illustrative embodiment of the invention;

Figure 2 is a top plan view of the refrigerant-heating assembly which is used during the defrosting of the evaporator unit;

Figure 3 is an enlarged front elevation of the refrigerant-heating assembly of Figure 2;

Figure 4 is a schematic diagram of the refrigerant circuit for the system; and

Figure 5 is a schematic diagram of the electrical circuit for the system.

In the storage of frozen food and the like it is desirable to avoid variations in the temperature because this tends to injure the food. Such variations of only a few degrees are often damaging, particularly where the variations are inherent in the refrigeration cycle so that the temperature is actually raised and lowered at frequent intervals. Therefore, the system should be such that the normal operation does not result in substantial variations; that is, the "cyclic swing" should not be great, and this makes it desirable to provide accurate thermostatic control. It is also desirable to avoid "carry over" periods after

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cooling is called for by the thermostat during which the compartment temperature continues to rise above the desired maximum temperature because the refrigeration system does not start cooling the evaporator immediately.

The problem of providing constant temperature conditions within a frozen food compartment is quite difficult particularly because of the marked tendency for frost to accumulate on the cooling surfaces which are the heat-exchange surfaces of the evaporator. Frost materially interferes with the efficiency of the evaporator by insulating the heat-exchange surfaces and by stopping the circulation of air through the interstices with the result that the compartment temperature tends to rise when the frost accumulates. Various arrangements have been provided for removing frost from evaporators but with low temperature operation these arrangements are not wholly satisfactory; they operate slowly so that the refrigeration operation is discontinued for a relatively long period of time, and the defrosting operation often causes an objectionable rise in the compartment temperature. When many direct-expansion refrigeration systems are operated at low temperatures there is a tendency for oil in the system to accumulate in the evaporator. This not only interferes with the normal circulation of refrigerant in the system but the oil tends to coat the inner walls of the evaporator so as to reduce the rate of heat-exchange. It is an object of the present invention to provide a low temperature refrigeration system which is free of the above objections.

In accordance with the present invention, the arrangement is such that the evaporator is kept free of excessive oil accumulations and the heat-exchange surfaces are kept free of frost; in this way the system operates efficiently at all times. Furthermore, the compartment is held at the desired temperature with a minimum variation even during the defrosting operation, and the operation is such as to reduce or even prevent the "carry-over" effects during operation.

In the illustrative embodiment of the invention, a direct expansion compressor-condenser system is provided where a single-stage compressor produces evaporation of the refrigerant in a single evaporator and the compressed gas is condensed in a condenser and then passed to a receiver. Each cooling operation is followed by a defrosting operation which thaws free any frost which has accumulated on the evaporator, and at the same time oil accumulations are purged from the evaporator with the result that the

evaporator is returned to its condition of maximum efficiency. During the cooling operation air is circulated over the heat-exchange surfaces to give rapid and efficient heat transfer, but this air circulation is stopped when the defrosting operation is started with the result that the heat which is introduced for the purpose of defrosting is not passed to the air in the compartment. At the end of the defrosting operation the compressor is operated sufficiently to condition the refrigeration system so that it is effective immediately when the thermostat calls for cooling; that is, the compressor is operated sufficiently to reduce materially the pressure and therefore the temperature within the evaporator, and when further cooling is called for the starting of the evaporator produces an immediate cooling effect. However, the temperature of the evaporator still remains above the compartment temperature and this characteristic may be used to anticipate a demand for further cooling of the compartment.

Under some conditions of operation after the evaporator is free of ice, the cooling operation is restarted immediately so that the complete cycle of operation is a cooling operation followed by a defrosting operation, and thereafter the cycle is repeated immediately with no "off" period. With this arrangement a relatively steady cooling effect is obtained, and the defrosting operation is so rapid that the compartment temperature does not vary.

The defrosting operation is performed by heating liquid refrigerant and passing the hot liquid through the evaporator. The refrigerant is heated by a group of electric heaters which are positioned in heat-exchange relationship with the liquid refrigerant coils, and the compressor is operated to circulate the hot liquid. A main control thermostat turns the compressor off so as to stop the refrigerating operation whenever a predetermined low temperature is reached in the compartment. In the illustrative embodiment a thermostatically controlled expansion valve is provided for the evaporator and at the beginning of the defrosting operation the temperature of the control bulb of this expansion valve is heated with the result that the valve is opened. Therefore, the heated liquid refrigerant passes freely into the evaporator so that the heat-exchange surfaces are heated rapidly. This insures that the defrosting operations are completed in a minimum period of time and with a minimum introduction of heat.

The main control thermostat for the compressor is exposed to the air in the compartment but it is located on the casing for the unit adjacent the refrigerant-heating assembly. This makes the thermostat somewhat responsive to the temperature of the unit, but its temperature is also influenced by the temperature of the storage compartment. Therefore, during the "off" period, this main thermostat is maintained at a temperature which is above that of the compartment. In this way when the compartment temperature tends to rise even only slightly, the thermostat calls for cooling and turns on the compressor.

In practice, the various factors may be such that the "cut in" temperature for the main thermostat is substantially above the temperature desired in the compartment and the thermostat may in a sense anticipate a demand for cooling. The entire system is so arranged as to avoid objectionable "carry over" effects. The evaporator is left free of frost and oil accumulations during the "off" period and the evaporator temperature is re-

duced sufficiently at the end of the defrosting operation to permit the system to start cooling within a very short period of time after the compressor has started. As stated above, when fans are used to drive the air over the evaporator during the cooling operation, these are rendered inoperative when the defrosting operation is started, and they remain inoperative, after the next cooling operation has started, until the evaporator temperature has been reduced substantially.

The system includes control mechanism which provides automatic control of the cooling operations, and by means of which the defrosting operation is normally carried on automatically. However, the arrangement is such that the defrosting operation may be controlled manually, or there may be semi-automatic control wherein the operator initiates the defrosting operation but relies upon the control mechanism to regulate the duration of the defrosting operation and the restarting of the cooling operation. This semi-automatic control permits the operator to initiate the defrosting operation at any time that this is desirable without depending upon the action of the automatic means which normally initiates the defrosting operation. For example, when a large amount of relatively uncooled food has been placed in the storage compartment or if the compartment has been out of use, the initial cooling operation may be quite extended so that the evaporator becomes frosted before the compartment temperature is reduced to the desired value. In such case the operator operates a manual switch to initiate a defrosting operation, and after the defrosting operation is thus initiated, it may be completed automatically. Under these circumstances the defrosting operation is completed in a minimum period of time and the cooling operation is then restarted immediately.

The control of the defrosting operation avoids the objectionable characteristics of a timed cycle in that this operation is continued only for a time sufficient to free the heat-exchange surfaces of frost. Thus, the defrosting operation is carried on without the introduction of an excessive amount of heat and there is ample assurance that all of the frost will be removed from the evaporator.

Referring particularly to Figure 1 of the drawings, the evaporator unit is indicated generally at 2, and has a finned coil evaporator (indicated at 3 in Figure 4) enclosed in a casing 4. The controls for the system are mounted on the right-hand end of casing 4 on a panel 5 and within a casing 6. The evaporator unit is mounted on a wall within the compartment to be cooled and air is drawn into the top of casing 4 by a pair of fans 8 each of which has a motor 10. The air passes down into the casing and through the evaporator and at the bottom of the casing it is deflected toward the front wall and is discharged in a horizontal direction through an elongated discharge port 12. A vane 14 is pivotally mounted above port 12 and is adjustable to control the size of the port. The bottom of the casing is formed by a trough-like drip pan 16 having a drain outlet 17.

The entire refrigeration system is represented schematically in Figure 4. Referring to the lower portion of the figure, a compressor 20 is driven by an electric motor 22 and the compressed refrigerant is discharged at the right to a condenser 24 where it is condensed. The liquid refrigerant passes from the condenser to a receiver 26 and from the receiver flows through a liquid pipe 27

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and the inside pipes of two heat-exchange units 25 and 28 in counter-current heat-exchange flow with the gas refrigerant returning to the compressor. From heat-exchanger 28 the liquid refrigerant flows through a coil 30 of a refrigerant-heating assembly 32 where the liquid refrigerant is heated during the defrosting operation.

From coil 30 the liquid refrigerant passes through a pipe 31 to an expansion valve 34 and thence to evaporator 3 through a pair of pipes which form a loop 35 which is part of assembly 32. Within the evaporator the liquid refrigerant evaporates and produces the desired refrigerating effect and the gas refrigerant passes back to the compressor through the following: a gas-heating loop 38 which forms part of assembly 32, the outer shell of heat-exchanger 28, a throttling valve 42 which is effective only during the defrosting operation, the outer shell of heat-exchanger 25 in counter-current flow to the liquid refrigerant, and a gas return line 40.

Expansion valve 34 is controlled by a thermostat having a bulb 50 clamped to loop 38 so as to be in heat-exchange relationship with the refrigerant gas passing from the evaporator back to the compressor. Mounted on motor 22 is a pressure switch which is operated by a Sylphon 51 which is connected to gas line 40. This pressure switch is normally open but, as will be explained below, when the pressure at the intake of the compressor exceeds a predetermined value, this switch is closed to operate the compressor.

Motors 10 which drive fans 8 are supplied with power from an electric circuit in a manner which is explained more fully below; however, these motors have connected in series with them a pressure switch 52 which has its Sylphon 53 connected through a gas pressure line 54 to an equalizing line 56 connected between the outer shell of heat-exchanger 28 and expansion valve 34. Switch 52 is normally closed but when the pressure in equalizing line 56 rises, the switch is opened so that the fans can not operate. Thus, when the temperature of the evaporator is below a predetermined value, switch 52 is closed because the pressure in equalizing line 56 is low. But, when the temperature of the evaporator rises, at times such as during the defrosting operation, the pressure rises in equalizing line 56 and switch 52 is opened. Therefore, the fans circulate air only when the desired cooling effect can be obtained, and during and after the defrosting operation the fans remain stationary.

The structure of the refrigerant-heating assembly 32 is shown best in Figures 2 and 3. Referring particularly to Figure 3, heat-exchanger 28 receives liquid refrigerant at the bottom through liquid pipe 27 and at the top the liquid passes through liquid line 29 into coil 30. Coil 30 is a tight-wound coil formed by flattened tubing with the turns of the coil having the configuration shown in Figure 2; thus, each turn of the coil has a front straight portion 60, a rear straight portion 62 and end loops 64 and 66. The front and rear straight portions 60 and 62 are in spaced parallel relationship and snugly engage the opposite sides of four flat resistance heater elements 65, 67, 68 and 69 (see Figure 3). These heating elements are electrically insulated from coil 30 but they are in good heat-transfer relationship with the coil. Thus, during the defrosting operation, when the heater elements are energized, the liquid refrigerant in coil 30 is heated in an efficient manner. The liquid refrigerant passes from the lower end of coil 30 through pipe

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31 into expansion valve 34 and from the expansion valve the refrigerant flows through loop 35 which passes below the bottom of coil 30 and (see Figure 2) thence upwardly inside of the coil along the edge of heater element 65. Thus, after passing through the expansion valve, the refrigerant is again passed into contact with the heater elements.

The heater elements are supported at the top by a bracket 71 and at the bottom by a similar bracket 72. Coil 30, expansion valve 34, heat-exchanger 28 and the other elements of the assembly are rigidly clamped to the heater elements. The electrical connections to the heater elements are provided through a pair of wires 74 and 75, and heater elements 65 and 67 are connected in parallel and thence in series with heater elements 68 and 69 which are also in parallel. Thus, there is a bus bar 76 connected to one terminal of each of the heater elements and a pair of bus bars 78 and 79 which are connected respectively to the other terminals of the two pairs of heater elements; bus bars 78 and 79 are connected respectively through a pair of thermostatic switches 77 and 81 to wires 74 and 75.

Referring now to Figure 5 where the electrical circuit for the system is represented schematically, power is supplied to the system at the right. The main power source is a 220-volt, 60-cycle source supplied through lines 80 and 82, and the main source for the control voltage is a 110-volt, 60-cycle source connected through lines 84 and 86. A main switch 88 is connected in lines 80 and 82, and a main switch 90 is connected in lines 84 and 86. An auxiliary switch 92 is connected in line 82 and a similar auxiliary switch 94 is connected in line 84, and these auxiliary switches are mechanically connected so that they are operated together.

The compressor motor 22 is adapted to receive current from lines 80 and 82 through a switch 96 which has an operating solenoid 98 which is energized to close the switch. Solenoid 98 has one side connected to line 80 and the other side connected through a line 100 to the fixed terminals of a normally-open pressure switch 102 and a normally-open switch 104 of a solenoid switch assembly 106. Switch 104 has an armature 103 and switch 102 has an armature 105; these armatures are connected to line 82 so that solenoid 98 is energized and motor 22 is started whenever either of switches 102 or 104 are closed. Switch 104 is closed during the refrigerating operation to energize the motor 22 and operate the compressor; and, switch 102 is closed during the defrosting operation by Sylphon 51 whenever the pressure at the intake of the compressor reaches a predetermined value, all in a manner to be more fully explained below.

Connected between lines 84 and 86 at the left of switch 94 is an indicating light 108 which is positioned on the control panel 5 to give an indication when the control circuit is energized. Line 84 is connected to the armature 110 of a defrosting-control switch 112 which has a left-hand contact 114 and a right-hand contact 116. Normally, armature 110 is positioned as shown in engagement with contact 114 and the system is defrosted automatically, but the defrosting operation may be initiated manually by moving armature 110 to the right into engagement with contact 116. Contact 116 is connected through a lead 118 to an indicating light 120 which is positioned on the control panel 5 (Figure 1), and

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which indicates that the defrosting operation is being carried on.

Contact 114 is connected through a lead 122 to an armature 124 of switch assembly 106. When in its lower position armature 124 engages a contact 126 which forms with the armature a switch unit 128, and when the armature is in the raised position it engages a contact 130 which forms with the armature a switch unit 132. Contact 126 is connected through a lead 134 to the temperature-responsive armature of a defrosting-control thermostat switch 136 which is mounted on the evaporator. Switch 136 has a right-hand contact 138 which its armature engages at fairly high temperatures and a left-hand contact 139 which its armature engages at fairly low temperatures. This switch is of the snap-action type and it is mounted adjacent the evaporator so as to be responsive to the evaporator temperature. Contact 139 is connected through a line 140 to a solenoid 141 of the defrosting relay switch 143. The other side of this solenoid is connected to line 86 so that when line 140 is connected to line 84 of the power source, the solenoid is energized.

The armature of switch 143 is connected to line 82 and its fixed contact is connected to line 74 which, as indicated above, is connected through switch 77 to one side of each of the heater elements 65 and 67. The other side of heater elements 65 and 67 is connected through a bus bar 76 to heater elements 68 and 69 which are connected through switch 81 to line 80. Connected in series between line 74 and line 80 are two pan-heater elements 145 which have a thermostatic switch 147 and are positioned in drip pan 16 at the bottom of casing 4 (see Figure 1). When solenoid 141 (Figure 5) is energized and switch 143 is closed, these heater elements are connected directly across lines 80 and 82. This keeps the drip pan warm during the defrosting operation so as to melt the frost which falls from the evaporator and so as to prevent the refreezing of the melted frost. However, the thermostatic switches are positioned adjacent their heater elements so that they open and close to maintain their heater elements at predetermined temperatures.

Contact 138 and contact 130 are connected through a line 142 to the armature of the main thermostat switch 144 which is mounted on panel 5. Switch 144 has a single contact 146 which is connected through a line 148 to one side of solenoid 150 of switch assembly 106. When solenoid 150 is deenergized armatures 103 and 124 are positioned as shown with switch 128 closed and with switches 104 and 132 open, and when solenoid 150 is energized the armatures are raised thereby opening switch 128 and closing switches 104 and 132. Contact 146 is also connected through a line 152 to pressure switch 52, which has been referred to above in the discussion of Figure 4, and which is connected in series with the fan motors 10; the other side of each of the motors is connected to line 86.

Contact 146 is also connected through a line 154 to an indicating light 156, the other side of which is connected to line 86. Light 156 is positioned on panel 5 (Figure 1) and when energized it indicates that the cooling operation is being carried on. Line 154 is connected to a switch 158 the other side of which is connected to a control line 160. The armature of switch 158 is mechanically connected to armature 110 of switch 112 so that when armature 110 is in the left-hand position switch 158 is closed, but when

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armature 110 is moved to the right switch 158 is opened. As will be explained more fully below, line 160 permits the remote control of the defrosting operation and it also permits the control functions of the arrangement of Figure 5 to be exerted upon remote units.

During operation, switches 88, 90, 92 and 94 remain closed, and, for automatic defrosting of the unit, armature 110 of switch 112 is in the left-hand position as shown. Assume that the cooling operation is being carried on with thermostat switch 144 closed but set to open when its temperature is reduced to 20° F. At this time solenoid 150 is energized by the circuit through line 148, switch 144, line 142, switch 132, line 122 and switch 112 to line 84. Thus, armatures 103 and 124 are held in raised position so that switches 104 and 132 are held closed and switch 128 is open. A circuit is also completed from line 84 and switches 132 and 144 to switch 52 which is closed so that the fan motors operate continuously. Furthermore, line 154 is connected to line 84 through switches 144 and 132 so that indicating light 156 is turned on and also so that control line 160 is energized.

Also assume that the defrosting-control thermostat switch 136 is in its left-hand position as shown but that it is adjusted so that it snaps to its right-hand position when its temperature rises to 33° F. and thereafter it snaps back to the left-hand position when its temperature falls again to 24° F. When the temperature of thermostat switch 144 falls to minus 20° F. the switch opens thereby deenergizing solenoid 150; thus, armatures 103 and 124 fall so that switches 104 and 132 are opened and switch 128 is closed. The opening of switch 104 deenergizes solenoid 98 and stops the compressor motor 22 so that the cooling operation is discontinued. The opening of switch 132 has no immediate effect because thermostat switch in series with it is already open, but this does isolate the thermostatic switch so that it is temporarily ineffective and if for some reason it should reclose immediately the reclosing would have no immediate effect upon the operation of the system.

The closing of switch 128 completes a circuit from line 84 through switch 112, line 122, switch 128 and line 134 to the defrosting-control thermostat switch 136; and, as indicated above, at this time the armature of switch 136 is in the left-hand position. Therefore, the closing of switch 128 closes a circuit through switch 136 and line 140 to solenoid 141 so that this solenoid is energized and the defrosting relay switch 143 is closed. As outlined above, the closing of switch 143 energizes heater elements 65, 67, 68, 69 and 145 so as to initiate the defrosting operation.

The opening of switch 144 also deenergizes the circuit of line 154 so that light 156 is turned off and control line 160 is deenergized; and the circuit of switch 52 is deenergized so that the fans are rendered inoperative and they do not blow air over the evaporator during the defrosting operation. The turning off of light 156 indicates to the operator that the refrigeration operation has been discontinued. The closing of switch 128 also completes a circuit from line 84 through switches 112, 128 and 136 to a line 162 and thence to line 118 with the result that indicating light 120 is turned on and this indicates to the operator that the defrosting operation is being carried on.

The defrosting operation can best be understood by referring to Figure 4 where, as indicated above, the various elements of the system are in-

licated schematically. The energizing of heater elements 65, 67, 68 and 69 heats the liquid refrigerant in coil 30 and in loop 35 with the result that the temperature and pressure within the evaporator rises very rapidly. This causes expansion valve 34 to open with the result that the hot refrigerant from coil 30 flows into the evaporator. There is also an immediate rise in the pressure in loop 38 and the normally-open throttle valve 42 closes automatically. The heating of the refrigerant produces a relatively high pressure condition, but the closing of valve 42 confines this condition to the evaporator. However, valve 42 has a by-pass vent of small cross-section which permits the high-pressure gas to flow slowly back toward the compressor into the outer shell of heat-exchanger 25. This flow of gas through the by-pass vent raises the pressure in the outer shell of heat-exchanger 25 and in the gas return line 40, and the arrangement is such that when this pressure reaches a value of 45 pounds per square inch the pressure acts through Sylphon 51 to close pressure switch 102 (Figure 5). This energizes solenoid 98 and starts the compressor motor. The pressure in line 40 is "pulled down" rapidly by the operation of the compressor, and, when this pressure reaches 15 pounds per square inch, switch 102 is opened and motor 22 is stopped. The flow continues through the by-pass vent of valve 42 so that the compressor is operated intermittently to give sufficient circulation of the refrigerant through the system to cause the liquid refrigerant which is heated in coil 30 to flow into the evaporator. Furthermore, the pressure in the gas return line 40 is kept at such a value that any liquid refrigerant which passes valve 42 will be evaporated in heat-exchanger 28 and therefore no liquid refrigerant reaches the compressor.

The thermostatic switches 77 and 81 maintain the refrigerant heater elements at a constant temperature so that the defrosting operation is carried on efficiently. The stopping of the fans prevents the heating up of the compartment during the defrosting operation and this avoids certain of the objectionable characteristics of prior systems referred to above. The frost is melted from the evaporator very rapidly and it is kept from refreezing by heater elements 145 so that it flows from the drip pan. As long as the evaporator has frost thereon its temperature is kept down to below 32° F., but as soon as there is no more frost to be melted the temperature of the evaporator rises. This causes the defrosting-control thermostat switch 136 (Figure 5) to snap to the right away from contact 139 and into engagement with contact 138. This deenergizes coil 141 and thereby opens switch 143 so as to deenergize the heater elements and discontinue the defrosting operation. At the same time line 162 is deenergized so that the defrosting-indicating light 129 is turned off. However, there is still a high pressure condition within the evaporator so that valve 42 (Figure 4) remains closed, and the high pressure gas flows slowly through the by-pass vent into the outer shell of the heat-exchanger with the result that the compressor is operated intermittently. This operation is such that the evaporator pressure is soon reduced to a value such that valve 42 reopens thereby connecting the compressor directly with the evaporator again.

When the defrosting operation has been completed the evaporator is free of ice and the pressure in the evaporator is reduced to a predetermined value such that its temperature is above

the normal temperature of the compartment. At this time the system is conditioned to produce cooling immediately upon demand by the thermostat switch 144. That is, the armature of thermostat switch 136 is in engagement with contact 138 so that with switch 128 closed, a circuit is completed through switch 136 and line 142 to thermostat switch 144. Therefore, at the time switch 144 closes, thereby calling for cooling, a circuit is completed to solenoid 150 with the result that the solenoid is energized and armatures 103 and 124 are raised. This closes switch 104 so as to start the cooling operation and the closing of switch 132 forms a by-pass hold-in circuit around thermostat switch 136 so that solenoid 150 remains energized as long as thermostat switch 144 remains closed. Thermostat switch 136 is so adjusted that it remains in engagement with contact 138 until thermostat switch 144 recloses. This adjustment is different for different types of installations, but for any particular installation it need not be changed during normal operation.

During and immediately after a defrosting operation, the pressure in the outer shell of heat-exchanger 25 and therefore in Sylphon 53, which controls pressure switch 52, is such that the switch is held open. Therefore, when the thermostat switch 144 calls for cooling, the fans are not started immediately. In this way the heat which is introduced into the evaporator for purposes of defrosting is not transferred to the air in the compartment. However, after the cooling operation has started, the evaporator temperature soon falls to such a value that switch 52 is reclosed and this starts fan motors 10 so that the fans are operated continuously until the cooling operation is completed.

As indicated above, a portion of the heat which is introduced to the evaporator for the purpose of defrosting is not withdrawn from the evaporator immediately and therefore the evaporator remains at a predetermined temperature which is above the normal compartment temperature. Thermostat switch 144 is so positioned that during the "off" period the thermostat switch is simultaneously cooled by the air in the compartment and heated by the heat from the evaporator. This thermostat switch may be so adjusted that it calls for cooling only when the temperature is reached in the compartment which indicated that cooling is desirable. That is, the cooling and heating effects on the thermostat switch are so balanced that the temperature of the thermostat switch is above the normal compartment temperature. Therefore, a change in conditions, such as, the entry of a warm draft of air, causes a sufficient rise in the thermostat switch temperature to cause it to "cut in" and start the compressor even though there has been no appreciable rise in the compartment temperature. In this way the temperature of the compartment is kept within very narrow limits of the desired temperature.

As indicated above, there are some conditions of operation wherein each defrosting operation is followed immediately by a cooling operation so that there is no "off" period. This mode of operation is obtained by proper adjustment of thermostat switch 144 so that the heating of the evaporator during the defrosting operation invariably closes thermostatic switch 144 before the defrosting operation is completed. The extremely rapid and efficient mode of defrosting the evaporator insures maximum utility and efficiency for

the system. Furthermore, by providing for the closing of switch 144 during each defrosting operation the temperature of the compartment can be kept within extremely close limits.

When it is desirable to defrost the evaporator manually, armature 110 of switch 112 is thrown to the right so as to deenergize the circuit of line 122, switch 132, thermostat switch 144 and solenoid 150 and thus stop the cooling operation. Upon armature 110 engaging contact 116 a circuit is completed from line 84 through lines 118 and 162 to line 140, and this energizes the defrosting relay solenoid 141 so as to energize the heater elements as described above. The energizing of line 118 turns on the defrosting indicating light 120. The defrosting operation proceeds as described above, except that when armature 110 is in its right-hand position the defrosting control thermostat switch 136 is ineffective to stop the defrosting operation; therefore, the operator throws armature 110 back to the left-hand position at the end of the defrosting operation. However, the defrosting operation will be carried to completion if armature 110 is thrown back to the left-hand position at any time after solenoid 150 has been deenergized and armatures 103 and 124 have fallen. Thus, in practice, the operator merely swings armature 110 to the right into engagement with contact 116 and holds the armature in this position for a short period of time; then he moves the armature back to the left and the defrosting operation is controlled automatically. This provision for the manual initiating of the defrosting operation is desirable when there is an extremely heavy load on the refrigeration system as, for example, when the refrigeration system has been out of service and it is turned on for the first time. In this way, if the operator observes that the evaporator is becoming frosted over, he can operate switch 112 to initiate the defrosting operation, but can rely upon the automatic controls for discontinuing the defrosting operation at the proper time and for conditioning the cooling operation.

As has been indicated above, line 160 permits remote control of the defrosting operation and also permits the transmitting of the control functions to remote units. In Figure 5 the showing is of the system so arranged that the control functions are exerted to one or more remote units. Accordingly whenever solenoid 150 is energized line 84 is connected to line 160. The arrangement in the remote units referred to can best be understood by assuming that it is desirable to control the arrangement of Figure 5 by a remote connection. For this purpose line 142 is disconnected from switches 144 and 136 with the result that switch 144 and the right-hand side of switch 136 are ineffective and exert no control functions. With this arrangement the defrosting operation is initiated by the energization of solenoid 150 through line 160 and switch 136 merely discontinues the defrosting operation when the temperature of this switch rises. Thus, when two or more units such as the one disclosed herein are connected in parallel the defrosting operations for all of the units are controlled by the thermostatic switches of only one of the units.

In Figure 4 evaporator 3 is represented schematically as a single pipe which receives liquid refrigerant through a loop 35 represented as a single pipe. However, evaporator 3 is formed by two equal sections of finned tubing connected in parallel, and, as shown in Figures 2 and 3, loop 35 is formed by a pair of small tubes 168 posi-

tioned in side-by-side relationship. It is important that the refrigerant be supplied evenly to these two tubes so that the two sections of the evaporator will be cooled properly. Accordingly, the ends of tubes 168 (see Figure 3) which receive the liquid refrigerant extend into an inverted L-pipe 170 which is much larger than the tubes so that the tubes extend through the L-pipe spaced from the walls thereof as shown in broken lines. The lower end of the L-pipe is brazed to the tubes so that a pocket is provided within the L-pipe and around the tubes.

Pipe 170 is coupled to expansion valve 24 by a flanged nut 172 and tubes 168 have their open ends projecting toward the stream of refrigerant which flows from the valve; and the refrigerant tends to divide equally between the two tubes. Furthermore, any foreign particles which enter pipe 170 from the expansion valve tend to pass into the pocket rather than into tubes 168. Thus, an efficient and dependable refrigerant distributing arrangement is provided and at the same time the pocket acts as an accumulator for foreign substances. This pocket is of sufficient size to receive the accumulation of foreign substances during long periods of use. While the pocket may be cleaned out, this is by no means necessary because this arrangement provides for the permanent trapping of foreign substances at a point in the system where the operation is not impaired. Even a substantial filling up of the pocket does not interfere with the flow and proper distribution of the refrigerant, and there is no tendency for substances which have entered the pocket to be freed again by the flow of refrigerant.

As many possible embodiments may be made of the mechanical features of the above invention and as the art herein described might be varied in various parts, all without departing from the scope of the invention, it is to be understood that all matter hereinabove set forth, as shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

I claim:

1. In a refrigeration system for maintaining a refrigerated space at a predetermined low temperature, the combination of, an evaporator positioned with the refrigerated space, a compressor to compress the refrigerant, condenser means to condense the compressed refrigerant, an expansion valve at the inlet to the evaporator, a heating coil to heat liquid refrigerant prior to passage to said expansion valve, a restricting valve positioned at the outlet of said evaporator which closes when the pressure in the evaporator reaches a predetermined value and which has a by-pass through which refrigerant flows at a slow rate when the valve is closed; and pressure-responsive means responsive to the pressure at the inlet to the compressor to start the compressor when the pressure reaches a predetermined value whereby during the defrosting operation the refrigerant which flows through said by-pass is compressed by the operation of the compressor thereby to circulate refrigerant through the system during the defrosting operation.

2. In a refrigeration system of the type wherein frost tends to accumulate upon the heat-exchange surfaces of an evaporator, the combination of, a compressor-condenser-evaporator unit which is adapted to produce a cooling effect at the evaporator by the evaporation of refrigerant and to then compress and condense the refrigerant, electrical means which is energized during

the defrosting operation to heat the liquid refrigerant prior to entry into the evaporator thereby to increase the pressure and temperature conditions within the evaporator sufficiently to melt the frost, valve means at the outlet from the evaporator to restrict the flow of refrigerant therefrom whereby the high pressure conditions are confined to the evaporator, and a heat-exchange unit to pass the liquid refrigerant flowing to the evaporator in heat-exchange relationship with the refrigerant flowing from the evaporator.

3. In a refrigeration system, control means comprising, a main relay switch which has a solenoid and which is energized to close the switch, a main thermostat switch which is closed to energize said solenoid, a lock-in switch which is in series with said main thermostat switch and which is closed when said main relay switch is closed thereby to hold the solenoid of said main relay switch energized, a defrosting switch which is closed when said main relay switch is open, a defrosting thermostat switch which is in series with said main defrosting switch and which opens when the defrosting operation has been completed, and a by-pass switch which is closed when said defrosting thermostat switch is open and which forms with said main defrosting switch a series circuit by-passing said lock-in switch whereby when the main relay switch is open the closing of said main thermostat switch energizes said solenoid and closes the main relay switch and the lock-in switch at the end of the defrosting operation.

4. In a refrigeration system of the type wherein refrigerant evaporates in an evaporator at such temperature that frost accumulates on the evaporator surfaces, the combination of, means to heat the refrigerant as it enters the evaporator whereby the temperature of the evaporator surfaces is raised sufficiently to melt the frost, a compressor to compress the refrigerant, fan means to direct a stream of air past said evaporator surfaces during the cooling operation, drive means to drive said compressor and said fan means, and control means including a first pressure switch which renders said fan inoperative when the evaporator pressure is above a predetermined value whereby the fans do not operate during the defrosting operation and a second pressure switch which operates said compressor to circulate the refrigerant through the system when the pressure at the intake of the compressor is above a predetermined value.

5. In a refrigeration system of the type wherein refrigerant evaporates in an evaporator at such temperature that frost accumulates on the evaporator surfaces, the combination of, electric heater means to heat the refrigerant as it enters the evaporator whereby the temperature of the evaporator surfaces is raised sufficiently to melt the frost, a compressor to compress the re-

frigerant, an electric motor to drive said compressor, fan means to direct a stream of air past said evaporator surfaces during the cooling operation, drive means to drive said fan means, and control means including a first pressure switch which renders said drive means for the fan means inoperative when the evaporator pressure is above a predetermined value whereby the fan means do not operate during the defrosting operation and a second pressure switch which turns on said electric motor and operates said compressor to circulate the refrigerant through the system when the pressure at the intake of the compressor is above a predetermined value.

6. In a refrigeration system which includes a compressor and a motor to drive the compressor, a control system comprising, a relay switch to start said motor, a pressure switch which is effective to close said relay switch when the pressure at a specific place in the system reaches a predetermined value, temperature-responsive means to close said relay switch when the temperature at a specific place in the system reaches a predetermined value, means to heat the refrigerant thereby to melt frost from the evaporator, and a defrosting-control means which initiates the stopping of the defrosting operation thereby to discontinue the heating of the refrigerant when the temperature of the evaporator reaches a predetermined value.

7. In a defrosting assembly in a refrigeration system of the compression-expansion type, the combination of, a heating coil through which the liquid refrigerant passes, an expansion valve which is closed only when the refrigerant leaving the evaporator is at a temperature substantially below the temperature of the refrigerant flowing into the evaporator, a plurality of electric heating units in heat-exchange relation with said coil whereby the refrigerant is heated, and a pressure-responsive valve connected in the outlet from the evaporator which closes automatically when the pressure within the evaporator reaches a predetermined value, said pressure-responsive valve having a restricted by-pass through which refrigerant passes at a slow rate from the evaporator when the valve is closed.

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