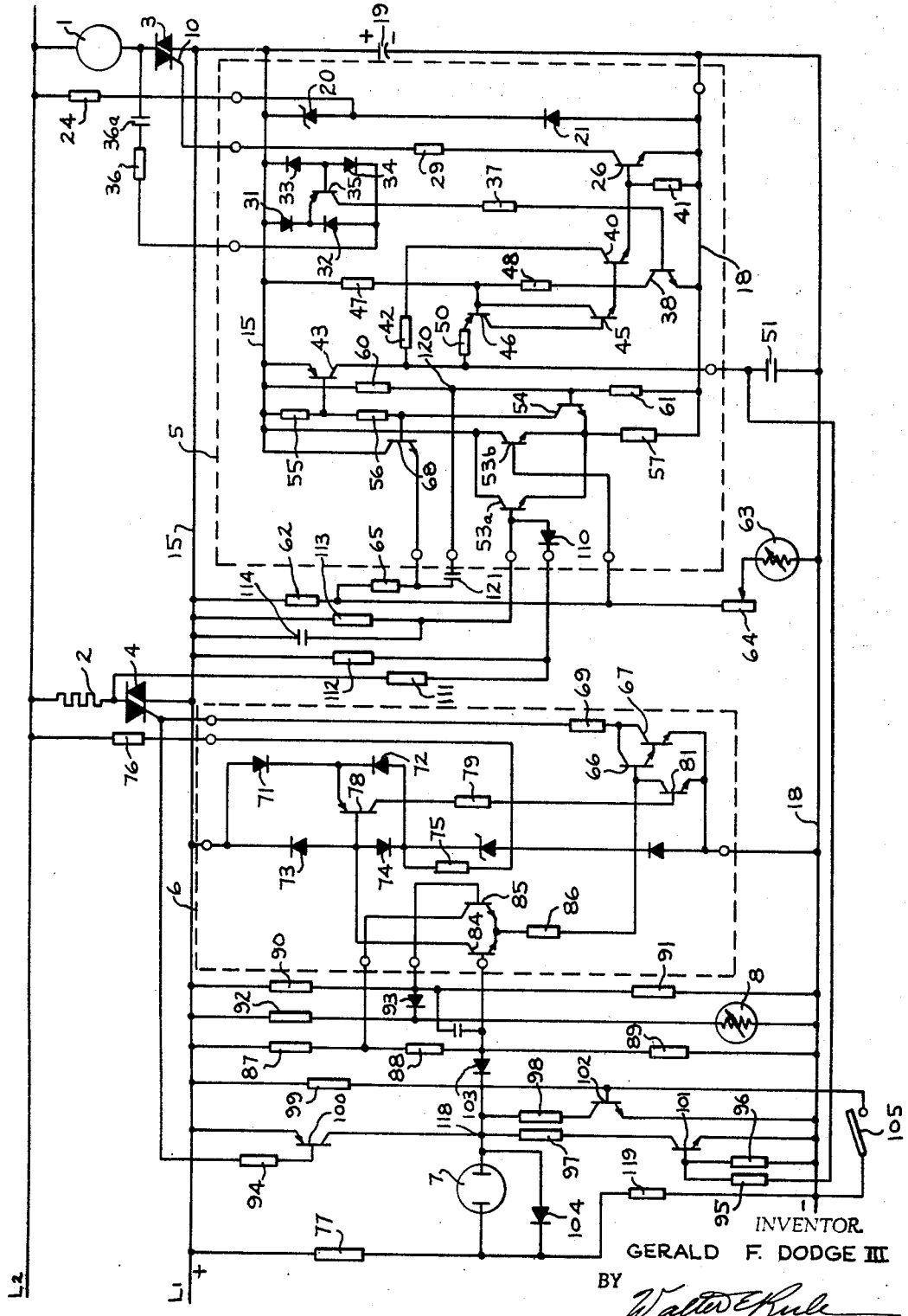
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ELECTRONIC REFRIGERATION SYSTEM DEFROST CONTROL

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ELECTRONIC REFRIGERATION SYSTEM DEFROST CONTROL

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ABSTRACT OF THE DISCLOSURE

An electronic control circuit for a refrigeration system having means for periodically initiating an evaporator defrost cycle comprises means for timing the initiation of a defrost cycle which includes a coulometer, means for charging the coulometer in one direction during refrigeration cycle operation and means operable when the coulometer has been charged to predetermined potential for initiating a defrost cycle. During the defrost operation, a current is passed through the coulometer in the opposite direction to reset its potential before the defrost cycle has been terminated by means including a thermistor.

BACKGROUND OF THE INVENTION

Many conventional refrigeration systems used in refrigerators and freezers include an evaporator which normally operates at below freezing temperatures with the result that a layer of frost accumulates on the surfaces thereof. For the most efficient operation of the refrigeration apparatus, it is necessary periodically to interrupt the refrigeration period and initiate a defrost period during which the evaporator is warmed to defrosting temperatures. Since the interruption of the refrigeration period and the warming of the evaporator to above freezing temperatures during the defrost period places an additional load on the refrigeration apparatus, it is desirable that a defrost period be initiated only when the frost build-up has reached a predetermined level. In recent years various solid state control circuits have been used or proposed for controlling the initiation of the defrost period. Such circuits described for example in Patents 3,248,892 Sutton et al. and 3,335,576 Phillips have included temperature sensing means such as a thermistor associated with the evaporator to initiate a defrost period when the temperature sensed by the thermistor reaches a preselected low temperature due to the accumulation of frost on the evaporator. It has also been proposed in refrigeration apparatus including air circulating means for circulating air from the compartment being refrigerated over an evaporator to initiate defost when the thermistor positioned in the path of the air flow passing over the evaporator senses a predetermined increase in the temperature of that air due to the accumulation of frost on the evaporator surfaces.

Neither of these control schemes is completely satisfactory under all conditions of operation of the refrigeration apparatus. One reason is that the frost build-up is generally not uniform over the entire evaporator surface and as the thermistor sensing means senses only the temperature of a relatively small surface area it is not directly affected by the presence or absence of accumulated frost on a different surface area. Also frost collected on an evaporator tends to migrate to the colder portions of the evaporator so that depending upon the positioning of the thermistor, the defrost period may be initiated too frequently or not frequently enough. Because of the disadvantages of temperature sensing defrost initiation, most present day refrigerators include defrost control means for initiating defrost period after a predetermined time

or alternatively after a predetermined total compressor operating time and such time control means have not incorporated the various advantages of solid state or electronic control circuitry.

SUMMARY OF THE INVENTION

The present invention has as its principal object the provision of an electronic refrigeration control system including a coulometric device for initiating a defrost period as a function of at least one operating condition of the system which is an analog of frost accumulation on the evaporator.

In accordance with the illustrated embodiment of the invention, the electronic control system includes solid state control circuitry for controlling the operation of the refrigerant compressor in accordance with the cooling requirements of a refrigerated compartment or other space being cooled, solid state control circuitry for controlling the energization of a defrost heating means and coulometric means for controlling the frequency of the defrost. During operation of the refrigeration operation of the apparatus, a relatively small direct current is passed through the coulometric device in one direction whenever the compressor is energized. When the coulometric device has thereby been charged to a predetermined potential, a defrost period is initiated and means are provided whereby during defrost operation a somewhat larger current is passed through the coulometric device in the opposite direction to reset the device for timing the period until a subsequent defrost is initiated. In accordance with a preferred embodiment of the invention as applied to a household refrigerator, the rate of charging of the coulometric device during a refrigeration period is a function of both compressor operating time and door open time. Therefore the interval between defrost cycles is a function of the compressor operating time and door open time.

BRIEF DESCRIPTION OF DRAWING

In the accompanying drawing, the single figure is a detailed circuit diagram of an electronic refrigeration control system embodying the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

While the electronic control system of the present invention is applicable to the control of any refrigeration apparatus in which the evaporator is subject to frost build-up, it will be particularly described with reference to refrigeration apparatus associated with a household refrigerator or freezer. It includes a motor driven compressor 1 which, in accordance with the well known practice, forms part of a refrigerating system including an evaporator (not shown) for cooling a refrigerated storage compartment. An electrical heating element 2 is provided for periodically warming the evaporator to defrost temperatures. The compressor 1 is connected across the alternating current power supply lines L1, L2 through a gate controlled conducting means such as a triac 3. The defrost heater 2 is similarly connected across the supply lines through a second gate controlled conducting means such as a triac 4. The triac is representative of commercially available gate controlled bidirectional conducting semiconductor switch means which can conduct current in either of two directions depending upon the polarity of the potential across its load terminals. For example, the bi-directional conducting triac can be triggered into a conducting state by a low voltage gating signal and once triggered, will remain conducting until the current flowing through the device is reduced below a minimum holding current value. This minimum holding current normally occurs with each polarity reversal of the current.

The triggering of the compressor control triac 3 during normal or refrigerating operation is controlled by solid state control circuitry including a component generally indicated by the numeral 5 which may be provided in monolithic integrated circuit form. The defrost function controlled by the triggering of triac 4 is controlled primarily by a solid state control circuitry generally indicated by the numeral 6.

The operation of the integrated circuitry 6 to initiate a defrost period is in response to a control signal developed by a coulometer 7 while the termination of the defrost period is effected by a control signal developed by a thermistor 8 which supplies such signal when the evaporator reaches an above-freezing or defrosting temperature.

Broadly the control circuitry of the present invention includes means for passing a direct current through the coulometer 7 during normal or refrigeration operation in a manner such that the charging of the coulometer 7 in one direction is proportional to a function of the frost build-up on the evaporator. When the coulometer obtains a predetermined charge, circuit means are provided for initiating a defrost period during which a somewhat larger direct current is passed through the coulometer 7 in the reverse direction so that it is reset for timing the subsequent interval leading to the next defrost period.

The triac gating circuits 5 and 6 are respectively zero crossing synchronous switching power circuits for non-unity and unity power factor loads and are of the types described in the copending applications of Donald L. Watrous and John D. Harnden, Jr., Serial Number 584,819 (now Patent 3,408,825) and Donald L. Watrous, Serial Number 584,702 both of which were filed October 6, 1966, and assigned to the same assignee as the present invention.

Turning now to more detailed description of the illustrated electronic refrigeration control system, the control gate 10 of the triac 3 is connected to the control circuitry 5 in a manner such that the triac 3 is rendered conductive just after the zero current crossing intervals of the supply alternating current is applied through the lines L1 and L2.

The synchronously operable control circuit means 5 for controlling the compressor 1 comprises means operatively coupled to the gate 10 of triac 3 for continuously providing synchronous low voltage gating pulses. This means comprises a DC power supply including a filter capacitor 19, a Zener diode 20 and a diode rectifier 21 connected across the filter capacitor. One terminal of capacitor and the cathode of Zener diode 20 are connected in common to power supply line L1 or 15. The remaining terminal of capacitor 19 is connected to the anode of diode rectifier 21 and the low voltage direct current gating potential terminal 18. The midtap point of Zener diode 20 and diode rectifier 21 is connected through resistor 24 to power supply terminal L2. As a consequence of this arrangement, the diode rectifier functions to develop a low voltage (in the neighborhood of about 8 volts) unidirectional gating potential across the filter capacitor 19 and terminal 18 which has the polarities indicated wherein the terminal of the capacitor connected to power supply line 15 is positive. Zener diode 20 operates to clamp the voltage across the terminals to the desired value.

The synchronously operable control circuit means also includes gating means comprising a junction transistor 26. The emitter of the transistor 26 is connected to negative terminal 18. The collector of the transistor 26 is connected through a limiting resistor 29 to the control gate of triac 3. By this arrangement, the transistor 26 is operatively coupled to the control gate of triac 3 and to filter capacitor 19, and when turned on, serves to apply a gating on signal to the triac 3 to cause the same to conduct load current through load 1. The transistor 26 has its base connected to the emitter electrode of an amplifying and commutating transistor 40 and its emitter connected to negative terminal 18 through resistor 41. The collector of transistor 40 is connected through resistor 42 to the collector of a transistor 43. Transistor 43 has its emitter connected to positive terminal 15 and its base to differential amplifier means to be described hereinafter.

The synchronously operable circuit means 5 further includes current zero sensing and turn on signal producing means formed by a diode bridge including diodes 31 through 34. One of the terminals of a set of opposed terminals (comprised by the cathode of diode 33 and the anode of diode 31) is connected to the power supply terminal 15. The other one of the same set of opposed terminals (comprised by the cathode of diode 34 and the anode of diode 32) is connected through a limiting resistor 36 and capacitor 36*a* to one of the load terminals of triac 3. Turn-on signal deriving means are operatively coupled across the remaining set of opposed terminals of the diode bridge for deriving a turn-on signal for eventual application to the gating transistor 26. This turn-on signal deriving means comprises a junction transistor 35 having its emitter connected to the juncture of the cathodes of diodes 31 and 32 and having its base connected to the juncture of the anodes of diodes 33 and 34. The collector of transistor 35 is connected through a limiting resistor 37 to the base of a second transistor 38 comprising a part of the gating means.

The transistor 40 has its base connected to the emitter electrode of a transistor 45 which is connected in positive feedback relation with a second transistor 46. For this purpose the transistor 45 has its collector electrode connected back to the base of the transistor 46, and the collector of the transistor 46 is connected back to the base of transistor 45. The base of transistor 46 is also connected between a pair of voltage dividing resistors 47 and 48 which are connected in series-circuit relationship with the emitter collector of the second gating transistor 38, the emitter of which is connected to terminal 18. The emitter of transistor 46 is connected through resistor 50 to the collector of transistor 43 and through resistor 50 and capacitor 51 to terminal 18.

The transistors 45 and 46 are interconnected in a positive feedback manner such that when the transistor 46 is turned on, both transistors are driven into saturation, and hence the voltage drop between their emitters is extremely low. These two transistors in conjunction with the capacitor 51 form in effect a relaxation oscillator.

Most of the elements 26–51 form a pulser circuit for turning triac 3 on near the beginning of each half cycle whenever transistor 43 is conducting. During normal conduction of the triac 3 during each half cycle, transistor 43 is conducting and the transistors 35 and 38 are maintained off due to the fact that there is a low and essentially constant voltage drop across the triac 3. As a consequence, the voltage applied to the base of the transistor 46 will be substantially that of the positive terminal 15 of the low voltage gating potential source. Since transistor 46 is a pnp transistor, this maintains transistor 46 turned off and capacitor 51 is allowed to charge to essentially the full potential of the positive terminal 15. Upon the current through triac 3 reaching zero, a voltage will be developed across the load terminals of the triac due to its returning to the blocking non-conducting condition. This voltage causes the transistors 35 and 38 to be rendered conductive, and results in applying a turn-on potential to the base of the transistor 46 by lowering its base voltage. Turn-on of transistor 46 also causes turn-on of transistor 45 due to their feedback connection and results in discharging capacitor 51 into the base of amplifying and commutating transistor 40 causing it to turn on and thereby turn on transistor 26. Conduction of gating transistor 26 results in applying a gating-on signal to the gate electrode of triac 3 at the beginning of the ensuing half cycle, thereby again rendering it conductive for the half cycle of the supply alternating current potential applied across terminals L1 and L2. Conduction of triac 3 removes the turn-on means of transistors 35 and 38 hence they turn off, allowing the base of 46 to be near the potential of 15. Concurrently conduction through the transistor 40 re-

duces the current to transistors 45 and 46 to turn them off and allows capacitor 51 to be recharged.

The signal for controlling the turn on of the transistor 43 is supplied by differential amplifier means comprising a plurality of npn transistors including transistors 53*a* and 53*b* and a reference transistor 54. The base of the transistor 43 is connected to the juncture of series-connected resistors 55 and 56 connecting the collector of the transistor 54 to the terminal 15. The emitter of transistor 54 as well as the emitters of 53*a* and 53*b* are connected by a common resistor 57 to the negative terminal 18. Also the collector of the transistors 53*a* and 53*b* are connected directly to the positive terminal 15. The base of the reference transistor 54 is connected between a pair of voltage dividing resistors 60 and 61 connected in series circuit relationship across the terminals 15 and 18. The base of the transistor 53*b* is connected to terminal 15 through a fixed resistor 62 and to terminal 18 through a thermistor 63 in the storage compartment space being refrigerated for sensing the temperature thereof and for deriving a control signal indicative of a change in temperature of this space. A variable resistor 64 in series connection with the thermistor 63 may be provided for selecting the control temperature range of the thermistor 63.

The voltage divider means comprising the resistors 60 and 61 for the base of the transistor 54 and the resistors 62, 64 and thermistor 63 for the base of the transistor 53*b* are so selected that when refrigeration is required, transistor 53*b* will be turned off and transistor 54 on thus supplying a turn-on signal to the base of the transistor 43. When no refrigeration is required transistor 54 is turned off and transistor 53*b* is conducting thereby turning off the transistor 43 and preventing firing of triac 3.

Also the junction between the resistor 62 and thermistor 63 is connected through a resistor 65 to the emitter of a transistor 68 having its collector connected to the terminal 15 and its base connected to the collector of transistor 54 which functions with the transistor 68 as a means of providing the desired difference between on and off temperatures at which the compressor is controlled.

The transistor 53*a* also has its base connected to an interlock circuit means for preventing operation of the compressor 1 during periods when the evaporator component of the refrigeration system is being defrosted by energization of the heater 2. Before describing this portion of the circuit, however, it is believed desirable to describe in detail the construction of the circuitry including synchronously operable control circuit means 6 for controlling conduction of the triac 4 and hence the energization of the defrost means 2.

The power supply for the means controlling the firing of the triac 4 are the positive and negative terminals 15 and 18. The control circuit means for the triac 4 also includes a pair of npn junction transistors 66 and 67 which are connected as conventional feedback coupled amplifiers wherein the collector of transistor 67 is connected to the collector of the transistor 66 and the emitter of the transistor 66 is connected to the base of the transistor 67. The emitter of the transistor 67 is connected to the terminal 18 while the common collectors of the transistors 66 and 67 are connected through a limiting resistor 69 to the control gate of the triac 4. Thus when the transistors 66 and 67 are turned on they apply a gating-on signal to the triac 4.

This circuit means 6 also includes sensing and turn-on signal producing means formed by a diode bridge similar to that previously described in connection with the operation of triac 3. However, its operation is somewhat modified by other components. Specifically, it comprises diodes 71 through 74 with the cathode of the diode 73 and the anode of the diode 71 connected to the positive terminal 15 and the cathode of diode 74 and the anode of diode 72 connected through the limiting resistors 75, 76 to the line L2. The transistor 78 in the diode bridge provides turn-on signal means and it has its emitter connected to the juncture of the diodes 71 and 72 and its base connected to the juncture of the diodes 73 and 74. The collector of the transistor 78 is connected through a limiting resistor 79 to the base of a shunting transistor 81 having its collector connected to the base of transistor 66 and its emitter to terminal 18.

The defrost heater control circuitry also includes a differential amplifier means including an input transistor 84 and a reference transistor 85 having their emitters commonly joined through a transistor 86 to the base of the transistor 66 and to the collector of the transistor 81. The collector of the transistor 84 is connected to the base of the transistor 78 while the collector of the transistor 85 is connected to the juncture between a resistor 87 and series connected resistors 88 and 89 across the terminals 15 and 18. The base of the reference transistor 85 is connected to the juncture of resistors 90 and 91 forming a voltage divider circuit across terminals 15 and 18 and also to the juncture of the circuit including resistor 92 and the thermistor 8 connected across the lines 15 and 18, this connection being through the diode 93.

It may be noted that the circuitry within the dotted line area 6 generally containing the elements 66 to 86 is available in integrated form from the General Electric Company and is identified as synchronous firing circuit PA424.

The potential at the base of the transistor 85 is, as previously indicated, controlled by the network consisting of the resistors 90, 91, 92, thermistor 8 and diode 93. When thermistor 8 is at a temperature below the defrost terminating temperature, the potential at the base of the transistor 85 is controlled by the resistors 90 and 91 so that the potential at the base of the transistor 85 is between that of the plus terminal 15 and the minus terminal 18. If the thermistor 8 is at a temperature above the defrost terminating temperature or warmer, this thermistor which has a negative temperature coefficient, has a resistance which is less than that of resistor 92 whereby the potential at the connection with the diode 93 becomes more negative than the junction on the opposite side of the diode 93 between resistors 90 and 91 with the result current will flow through the diode 93 and lower the base potential of the transistor 85. It will be understood of course that the thermistor 8 is in heat exchange relationship with the evaporator for the purpose of terminating a defrost cycle at an above-freezing temperature of the evaporator.

In addition to the resistors 77, 87, 88, 89, 119 the circuitry controlling potential at the base of the transistor 84 includes resistors 94 through 99, transistors 100, 101, 102, diodes 103 and 104, the coulometer 7 and certain components and conditions within the integrated circuit 6.

The coulometer 7 has one lead connected to the junction of resistors 77 and 119 across the terminals 15 and 18. The other or right hand terminal is connected through the transistor 100 to the positive terminal 15, the base of this transistor being connected through a resistor 94 to the gate of the triac 4. This right hand lead is also connected through a resistor 97 and transistor 101 to the negative terminal 18 with the base of the transistor 101 connected to the negative terminal through a resistor 96 and to the emitter of transistor 43 through a resistor 95.

This circuitry provides control of the defrost heater by the coulometer 7 and initiates defrost based on a predetermined period of total compressor operating time. In accordance with the preferred embodiment of the invention door opening time is also integrated into the circuit and this is accomplished by means including a resistor 98 and transistor 102 connecting the right hand lead of the coulometer 7 to the negative terminal 18 with the base of the transistor 102 connected through a door switch 105 to the negative terminal 18 and through resistor 99 to terminal 15. Door switch 105 is conductive when the door is closed.

Before explaining the operation of the defrost timnig control means including the coulometer 7, additional con-

trol and lock-out circuitry for controlling the alternate refrigeration and defrost operations should be referred to. This circuitry includes a diode **110** having its anode connected to the base of the transistor **53***a* and its cathode connected through a resistor **111** to the junction between the defrost heater **2** and the triac **4** and by resistor **112** to the positive terminal **15**. The base of the transistor **53***a* is also connected to a time constant circuit including resistor **113** and a capacitor **114** which are connected to the positive terminal **15**. By this circuitry, if the triac **4** is not conducting, essentially the voltage of line **L2** will be present at the triac end of the resistor **111**. The resistances **111** and **112** form a network which reduces the voltage at the cathode of the diode **110** to about 1/10 the **L1** to **L2** voltage. The voltage is rectified by diode **110** and offsets the current to the base of the transistor **53***a* by the resistance **113** such that the voltage at the base of the transistor **53***a* is negative with respect to the voltage at the base of reference transistor **54**. The result is that the transistor **53***a* will not conduct to turn off transistor **54** and thereby transistor **43** to inhibit conduction of the compressor triac **3** so long as the defrost switching triac **4** is not conducting.

In explaining the operation of the coulometer **7** in periodically initiating the defrost operation, it will be assured that the switching circuitry is in a condition such that the triac **4** is not conducting, the triac **3** is periodically energizing the compressor **1** and the evaporator sensing thermistor **8** is at a below freezing temperature. The coulometer **7** is not fully charged and is then accepting a charge whenever the triac **3** is conducting and the voltage across its terminals is of an order of magnitude of about 0.2 to 0.4 volt. One lead of the coulometer **7** is connected to the common point of the resistors **77** and **118** and since these two resistors are about of equal resistance the potential at that common point is about ½ of the power supply potential from terminals **15** and **18** if the current through the coulometer **7** is very low. Since the terminal voltage of the coulometer **7** is only 0.2 to 0.4 volt, the common point **118** of the transistor **100**, the resistors **97**, **98** and the diode **103** at the opposite lead of the coulometer is also essentially ½ of the DC power supply voltage.

The resistors **87**, **88** and **89** have values that cause the base of the transistor **84** to be at about ½ of the direct current power supply potential but still positive with respect to the base of the transistor **85** so transistor **84** is conducting. The collector of the transistor **85** connected between the resistors **87** and **88** has no current flow. With the base of the transistor **84** at about ½ of the DC power supply voltage but still positive with respect to the base of the transistor **85** no current will flow through the diode **103**, the defrost triac **4** is not switched on and the compressor continues to run under the control of thermistor **63**.

When the compressor is running, a current supplied from the emitter of the transistor **43** through the resistor **95** to the base of the transistor **101** biases the transistor **101** into conduction. Current is now free to flow through the resistor **77**, the coulometer **7**, the resistor **97** and the transistor **101** and the magnitude of this current is controlled by the resistor **97**. The current flow and charge capacity of the coulometer **7** determines the amount of compressor running time which will be allowed before the coulometer is fully charged and a defrost period is initiated.

In the illustrated circuitry, current can also flow through resistor **77**, coulometer **7**, resistor **98** and transistor **102** when the door switch **105** is open so that it does not bleed off the gating potential at the base of the transistor **102**. In other words, the current to bias the transistor **102** to conduction is provided by the resistor **99** when the door switch **105** is opened and not shunting the base emitter junction of the transistor.

After sufficient current has passed through the coulometer **7**, the voltage across its terminals increases. The effect of this increase is the lowering of the potential at the common point **118** so that current flows through the diode **103** and lowers the potential at the base of the transistor **84**. When the potential at **118** is lower than the potential of the base of the transistor **85**, the transistor **84** turns off and the transistor **85** turns on with the result that current is not continuously shunted through the base of the transistor **78** turning off transistor **78** and the shunting transistor **81** and allowing turn-on of transistor **66**, **67** to gate the triac **4** at zero voltage crossing.

When the triac **4** is turned on to energize the defrost heater, current flow through resistor **87** to the collector of the transistor **85** causes both the collector and base potentials of the transistor **85** to become more negative and the result of this current flow is great enough that the potential of the base of the transistor **84** remains more negative than the base of transistor **85** until the thermistor **8** resistance decreases sufficiently from defrost heat to reduce the potential of transistor **85** base by means of current flow through diode **93**. This is true even though the current flow through the diode **103** ceases.

Also the conduction of the defrost triac **4** in series with the defrost heater **2** results in removal of the AC voltage from the cathode of the diode **110**. This permits current to flow through the resistor **113** and thereby raise the potential at the base of the transistor **53***a* above the potential at the point **120** between the resistors **60** and **61**. This causes transistor **53***a* to conduct and turns off transistor **54**. With transistor **54** off, transistor **43** is off and the triac **3** is turned off and cannot be turned on until the AC voltage is restored to the cathode of the diode **110**.

Also the gate lead of the triac **4** in series with the defrost heater **2** has a voltage that approximates a square wave when this triac is conducting. The voltage present at the gate is alternatively positive with respect to line **L1**. The transistor **100** is thereby turned on by current flow from the line **L1** through the transistor **100** and the resistor **94** into the triac gate when the gate is negative. The transistor **100** allows current to flow into the coulometer **7** through the resistor **118** to the negative terminal **18**. The current flow through the transistor **100** and the coulometer is in opposite direction to the current through the transistors **101** and **102**. The current is limited only by the resistance **93** and is of sufficient magnitude to reset the coulometer by reversing the coulometer polarity during the shorter defrost period.

If the reset current is allowed to flow through the coulometer during a long defrost the terminal voltage would rise too high and damage the coulometer. For that reason the diode **104** is provided for passing excess current limiting the reset voltage and preventing the voltage from rising high enough to injure the coulometer. It may be noted also that the diode **103** prevents the voltage of the coulometer from driving the base potential of the transistor **84** more positive than the potential of the base of transistor **85**.

The reset current for the coulometer **7** or diode **104** bypass flows until sufficient heat has been supplied to the evaporator to defrost and raise the evaporator above the freezing temperature as sensed by the thermistor **8**. When this temperature reaches for example 50° F., the resistance of thermistor **8** decreases enough to cause the base of the transistor **85** to be more negative than the base of the transistor **84**. Transistor **84** then conducts and causes transistors **71** and **81** to conduct continuously. When this occurs the triac connected in series with the defrost heater is turned off and when this triac is turned off the lockout circuitry including transistor **53***a* for the triac **3** is removed and the compressor is returned to the control of the thermistor **63**.

Any suitable coulometer may be employed for the purposes of this invention. A particularly useful coulometric device is that shown and described in Patent 3,302,091—Henderson issued January 31, 1967, to which reference is hereby made for a complete description thereof.

What I claim as new and desire to secure by the Letters Patent of the United States is:

1. An electronic control system for controlling a refrigeration apparatus including an evaporator subject to frost build-up during refrigerating operation of said apparatus and defrost means for defrosting said evaporator during defrost operation of said apparatus comprising:

a defrost control circuit means for initiating the defrost operation comprising a coulometric device, means for passing a direct current through said coulometric device in one direction during refrigerating operation of said apparatus, and means operable upon a charging of said coulometric device to a given potential for energizing said defrost means, and

means for reversing the flow of current through said coulometric device during defrost operation of said apparatus.

2. The system of claim 1 including means responsive to the temperature of said evaporator for terminating said defrost operation.

3. An electronic control system for controlling the operation of a refrigeration apparatus including a compressor, an evaporator subject to frost build-up and defrost means for periodically defrosting said evaporator comprising:

a cooling control circuit means for controlling the periodic energization of said compressor during refrigerating operation of said apparatus.

a defrost control circuit means for controlling the energization of said defrost means;

means for timing the period between defrost operating periods of said defrost means comprising a coulometer,

means for passing a direct current through said coulometer in one direction during refrigerating operation of said apparatus,

means operable upon a charging of said coulometer to a given potential for energizing said defrost means; and

a compartment adapted to be refrigerated by said apparatus, a door for closing the access opening to said compartment and means to pass a current through said coulometer in said one direction when said door is open.

4. The system of claim 3 in which the current passed through said coulometer in said one direction is larger when said door is open than when said compressor is energized.

5. A refrigerator including a storage compartment, an electronic control system for controlling the operation of a refrigeration apparatus including a compressor, an evaporator for cooling said compartment and subject to frost build-up and defrost means for defrosting said evaporator comprising:

a cooling control circuit means for controlling the periodic energization of said compressor during refrigerating operation of said apparatus;

a defrost control circuit means for controlling the energization of said defrost means to effect defrost operation of said apparatus;

and means for timing the initiation of the defrost operation of said defrost means comprising a coulometer, means for passing a direct current through said coulometer in one direction during energization of said compressor, means operable upon a charging of said coulometer to a given potential for energizing said defrost means, and means including a thermistor responsive to the temperature of said evaporator for terminating said defrost operation.

6. The refrigerator of claim 5 including a door for closing the access opening to said compartment and means including a door operated switch means for also passing a current through said coulometer in said one direction when said door is opened.

7. The refrigerator of claim 5 including means for reversing the flow of current through said coulometer during defrost operation.

8. The refrigerator of claim 7 including means in said control circuit for assuring termination of a defrost operation only by said thermistor.

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MEYER PERLIN, Primary Examiner

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