

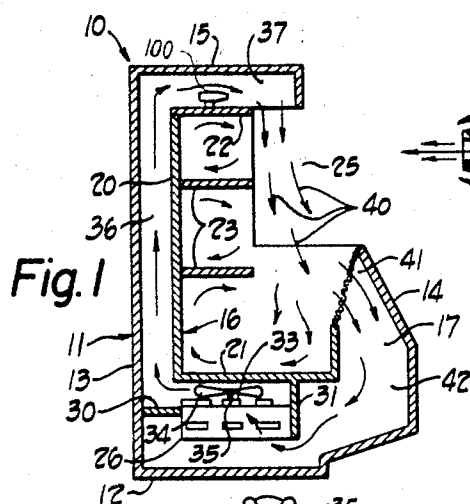
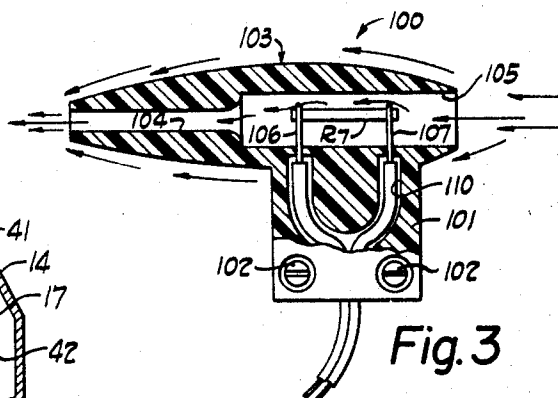
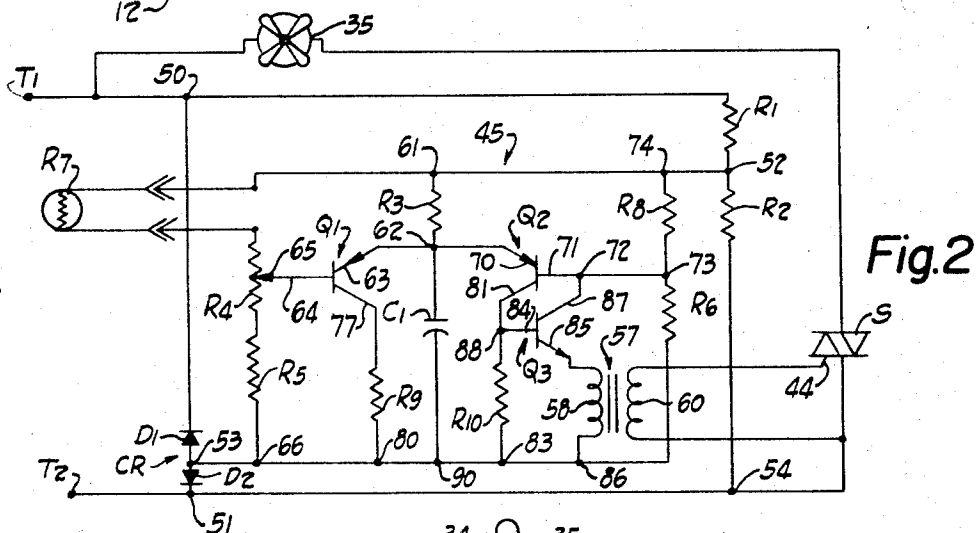
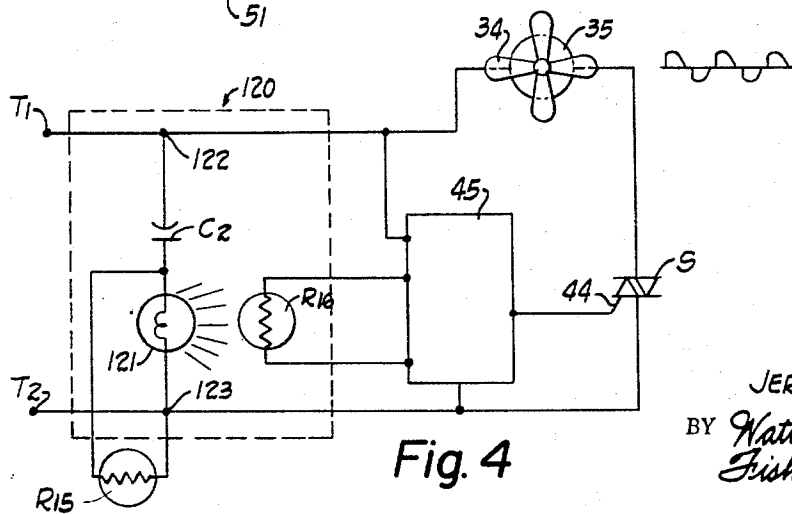
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J. L. LORENZ

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CONTROL APPARATUS FOR REFRIGERATED DISPLAY CASE

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INVENTOR.
JEROME L. LORENZ
BY *Watts, Hoffmann,
Fisher & Heinke*
ATTORNEYS.

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3,444,698 CONTROL APPARATUS FOR REFRIGERATED DISPLAY CASE

Jerome L. Lorenz, Columbus, Ohio, assignor to
Ranco Incorporated

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11 Claims

ABSTRACT OF THE DISCLOSURE

A refrigerated display case for receiving articles to be maintained at subfreezing temperatures and including a case structure defining a chamber for receiving articles to be displayed, air ducts, an air cooling heat exchanger supported by the case structure, an electrically energized blower for directing air in a circuit through the ducts and across an open side of the chamber in an air curtain, and control apparatus for maintaining a constant cooling capacity of the air in the curtain in response to sensed temperature and velocity of that air. In one disclosed embodiment the control apparatus includes a self-heated thermistor disposed in a metered flow of duct air having a variable resistance depending on the temperature and velocity of air passing thereacross, a light source connected in circuit with the thermistor for producing light having an intensity which varies in response to changes of temperature and velocity of the air, and a light responsive resistor adjacent the light source for producing a control signal in response to changing intensity of the light source to vary the speed of the blower accordingly.

The present invention relates to refrigerated display cases and more particularly relates to display cases of the type utilizing an air curtain of refrigerated air to maintain subfreezing temperatures of articles or produce being displayed. Self-service refrigerated food display cases utilizing the principle of an air curtain for cooling food stuffs, produce, etc. while providing a barrier to prevent entrance of ambient air into the case have become relatively common, particularly when used to display food stuffs being maintained at temperatures above the freezing temperature of water. In display cases of the type referred to an air cooling heat exchanger is supported within the casing and blowers are utilized to circulate air across the heat exchanger and through ducts in the case which are to be directed in a curtain across an open side of an article receiving chamber defined by the case. When the food stuffs within the chamber are maintained above freezing temperatures, and the air cooling heat exchanger is also maintained at a temperature above the freezing temperature of water, maintenance of the food stuffs at the desired temperature has been relatively easily accomplished.

Merchandising of frozen foods as well as foods maintained at temperatures only slightly above the freezing point of water utilizing air curtain display cases of the type referred to has become desirable; however in such circumstances it is necessary to utilize an air cooling heat exchanger which is maintained at a subfreezing temperature and is inherently subject to frost accumulation. Such cases are also subject to frost accumulation of the produce displayed in the case which is undesirable since the produce becomes unattractive or unrecognizable to prospective purchasers.

The frozen food displayed in cases of the type referred to is maintained at subfreezing temperatures by the re-

frigerated air forming the air curtain so that the air curtain chills the produce while providing a barrier which prevents moist ambient air from entering the refrigerated case and frosting the produce therein. The cooling capacity of the air curtain is a function of its velocity and temperature and, since the velocity of the air curtain is proportional to the mass flow rate of air and its temperature, the velocity is proportional to the heat content of the air curtain. Thus, a low temperature high velocity flow of air in the curtain produces a relatively large cooling effect while higher temperature, lower velocity air in the air curtain has a smaller cooling effect. It has been discovered that if the velocity of air in the air curtain is relatively high, moist atmospheric air surrounding the display case is entrained in the air curtain and drawn across the heat exchange surfaces of the air cooling heat exchanger resulting in relatively rapid frost accumulation on the heat exchanger which necessitates frequent defrosting. On the other hand if the velocity of the air curtain is relatively low, moist atmospheric air penetrates the air curtain and enters the display case causing frost to sublime on the displayed product.

In display cases of the type mentioned it is common to provide an air cooling heat exchanger which operates at a substantially constant temperature. When frost accumulates on heat exchange surfaces of such an exchanger the frost insulates the heat exchange surfaces from the air and reduces the rate of heat transfer from the air to the cooling medium in the heat exchanger. In such circumstances the temperature of air in the air curtain is increased in accordance with the reduced heat transfer rate. Moreover accumulation of frost on the heat exchange surfaces tends to throttle the air flow across the heat exchanger, reducing the velocity of the air to be directed into the air curtain accordingly.

Defrosting of such display cases is controlled various ways such as by the use of times for initiating and terminating defrosting at fixed intervals, frost sensing apparatus for initiating and terminating defrosting cycles in response to sensed frost accumulation on the heat exchange surfaces, etc. Regardless of the mode of controlling defrosting however, the flow of air across the heat exchange surfaces is affected in the manner set forth by the inevitable frost accumulation on the heat exchanger. Furthermore the cooling capacity of an air curtain particularly the air velocity can vary widely and in an uncontrolled manner during a refrigeration cycle of the apparatus resulting in unduly rapid frost accumulation at the beginning of the cycle and sublimation of frost on the product at the terminal portion of the cycle.

Summary of the invention

The present invention provides control apparatus for modulating the flow rate of air across a heat exchanger of a display case of the type referred to so that heat transfer rates from the air to the heat exchanger are maintained at a relatively constant level during a refrigeration cycle. The air curtain velocity is maintained at an optimum level for any given frost condition of the heat exchanger to thereby produce a substantially constant cooling capacity of the air curtain during the refrigeration cycle.

More specifically, the invention contemplates a control apparatus operative to modulate the blower speed in an infinite manner so that when the heat exchanger is relatively frost free the air curtain velocity is relatively low and the rate of frost accumulation on the heat exchange surfaces is diminished from that which is other-

wise obtained. As the heat exchanger becomes laden with frost the blower speed continuously increases so that adequate heat is transferred from the air to the heat exchanger to maintain a uniform cooling capacity of the air in the air curtain and since the curtain velocity is increased sublimation on the displayed products is avoided.

Accordingly a principal object of the present invention is the provision of a new and improved control apparatus for a self service display case of the type referred to wherein the velocity of air in the air curtain is maintained at a rate which minimizes the accumulation of frost on an air cooling heat exchanger of a refrigeration system of the display case as well as minimizes sublimation of frost on the product being displayed during refrigeration cycles of the refrigeration system.

Another object of the present invention is provision of a new and improved control apparatus for a refrigerated display case wherein refrigerated air is propelled across an air cooling heat exchanger and in a curtain across the display case by electrical motor driven blowers and wherein the apparatus modulates the speed of operation of the blowers in response to sensed air curtain heat capacity so that heat transfer from the air to the heat exchanger is maintained relatively constant during a refrigeration cycle and the velocity of the air curtain is maintained at an optimum level for any given frost condition of the heat exchanger.

In carrying out the present invention, control apparatus for a blower motor is provided which is effective to regulate the electrical power supplied to the blower motor in response to sensed air curtain velocity and which apparatus includes a self-heated thermally responsive electrical resistance element mounted in a flow passage for refrigerated air so that the amount of heat transferred away from the thermally responsive resistance element is indicative of the velocity of the stream of air flowing across the element and wherein the aperture regulates the speed of the blower motor in a continuous manner in response to the sensed air velocity via the thermally responsive resistor. In one embodiment of the invention the temperature responsive element is connected in circuit with an incandescent lamp which is positioned adjacent a light sensitive resistance element connected into motor speed control circuitry so that sensed velocity of the refrigerated air controls the intensity of light produced by the incandescent lamp and operation of the motor speed controlling circuitry in response to sensed velocity is modulated by the incandescent lamp and light sensitive resistance element.

Other objects and advantages of the present invention will become apparent from a consideration of the following detailed description thereof made with reference to the accompanying drawings which form a part of the specification and wherein:

FIG. 1 is a sectional view of a schematic refrigerated display case embodying the present invention;

FIG. 2 is a schematic diagram of motor speed controlling circuitry forming a part of the apparatus of FIG. 1;

FIG. 3 is a fragmentary sectional view of a mounting member for a velocity sensitive element forming a part of the apparatus of FIG. 1; and

FIG. 4 is a schematic illustration of a modified motor speed controlling circuit similar to that shown in FIG. 2.

A self service refrigerated food display case 10 is illustrated in FIG. 1 and includes a cabinet 11, shown schematically, including a base or supporting portion 12 and rear, front and top walls 13, 14 and 15 respectively. The display case 10 also defined an open sided compartment 16 defined by side walls 17 of the cabinet only one of which is illustrated, a rear panel 20 spaced from the rear wall 13 of the cabinet 11, a bottom or lower panel 21, a top panel 22 and shelves 23. The lower panel 21 and shelves 23 support frozen food stuffs or products as is usual and which products are inserted and removed

from the compartment 16 through the opening 25 formed in the front wall 14 of the cabinet.

The products within the case 10 are maintained at temperatures below the freezing point of water by a flow of refrigerated air which is circulated within the cabinet 11 and in a curtain across the opening 25. An air cooling heat exchanger 26 is supported within the cabinet 11 by suitable brackets 20, 21 which are connected to the rear wall 13 and the lower panel 21, respectively. The air cooling heat exchanger 26 is thus positioned beneath the lower panel 21 and extends substantially between the side walls 17 of the casing 11. While the air cooling heat exchanger 26 may be of any suitable type, generally display cases 10 of the type illustrated in FIG. 1 are provided with a compressor-condenser-evaporator type refrigeration system and the illustrated air cooling heat exchanger 26 corresponds to the evaporator of such a system. A refrigerating medium is circulated in a controlled manner through the exchanger 26 by conventional means (not shown) so as to maintain the temperature of the exchanger somewhat below the temperature to be maintained in the case 10.

A blower 33 is provided for circulating air across the air cooling heat exchanger 26, through suitable ducts formed in the display case 10, across the opening 25 in a curtain from which the air is returned to the air cooling heat exchanger 26 through return ducts in the display case. The blower 33 includes a fan member 34 and an AC induction motor 35 for driving the fan member to produce the flow of refrigerated air through the above mentioned circuit, and although only a single blower 33 is illustrated, it should be understood that a plurality of such blowers are provided at spaced locations along the extent of the air cooling heat exchanger 26.

When the blower 33 operates, air is drawn through the air cooling heat exchanger 26 and heat is transferred from the air as it passes across fins or similar heat exchange surfaces of the heat exchanger 26, after which the air is directed through a duct 36 defined by the rear wall 13 and the rear panel 20, a duct 37 defined by the upper panel 22 and the upper wall 15 of the cabinet and is discharged in a curtain generally designated by the arrows 40 across the opening 25. Air in the curtain 40 is returned to the air cooling heat exchanger 26 through a screenlike grate 41 and a duct 42 defined by the front wall 14 of the cabinet 11 and lower panel 21 of the compartment 16.

The refrigerated air flowing in the air curtain 40 transfers heat away from the frozen products disposed in the compartment 16 to maintain the products at a relatively low temperature; the ability of the refrigerated air curtain to transfer heat from the product being proportional to the mass flow rate of air in the curtain and its temperature. As the chilled air in the curtain 40 is circulated in the case the relatively moist atmospheric air adjacent the opening 25 is urged into the curtain 40 due to the difference in partial water vapor pressures between the chilled and atmospheric air as well as the reduced static pressure of the moving curtain air. The moist air entrained in the air curtain deposits the moisture therein on the heat exchanger 26 in the form of frost, thus insulating the heat exchanger from the surrounding air. As a consequence of the insulating effect of frost on the heat exchanger, the temperature of the air flowing across the heat exchanger tends to be elevated thus tending to reduce the cooling capacity of the air in the air curtain. In such circumstances the cooling capacity of the air curtain can be increased by increasing the velocity of the air flow across the heat exchanger to thereby increase the rate of heat transfer from the air to the heat exchanger.

It has been found that the provision of relatively high velocity air curtain flows to compensate for the insulating effects of frost on the heat exchanger is not desirable since high velocity air curtain flows entrain relatively

large amounts of moist atmospheric air into the curtain causing unduly rapid frost accumulation on the heat exchanger and requiring frequent defrosting of the heat exchanger. If air curtain velocity is maintained at levels which produce relatively economical rates of frost accumulation early in a refrigeration cycle, the frost accumulation throttles the air flow across the heat exchanger at the terminal portion of the refrigeration cycle. Throttling of the air flow can reduce the air curtain velocity to a level which permits atmospheric air to penetrate the curtain and sublime moisture on the displayed product which is undesirable.

According to the present invention control apparatus is provided for maintaining the cooling capacity of the refrigerated air curtain 40 relatively constant by modulating the flow rate of air across the heat exchanger as frost accumulates thereon. Additionally the velocity of the air curtain is maintained at optimum levels for minimizing sublimation of frost on the displayed product and on the heat exchange surfaces of the air cooling heat exchanger 26 at any particular frost condition of the heat exchanger. More particularly, the control apparatus referred to is effective to govern the amount of power supplied to the AC induction motor 35 which drives the blower member 34 so that the speed of operation of the motor 35 is governed according to sensed cooling capacity of the air curtain 40.

FIG. 2 illustrates a schematic control apparatus embodying the invention which includes a semiconductor switch S having its power electrodes connected in series with the AC induction motor 35 across terminals T1, T2 of an AC power supply, preferably 117 v. AC, 60 cycle power which is available in a typical commercial establishment. The switch S is of the type known as the silicon gated switch and includes a control electrode 44 which, when pulsed, renders the switch S conductive regardless of the polarity of the voltage across the power electrodes of the switch. In the absence of pulses to the control electrode 44, the switch S is nonconductive and the motor 35 is not energized.

When an electrical pulse or signal is received at the control electrode 44 of the switch S during a positive half cycle of the power supply a motor energizing circuit is completed from the terminal T1 through the windings of the motor 35, the switch S and to the terminal T2. During a negative half cycle of the power supply and when a pulse is received at the control electrode of the switch S the motor 35 is energized through a circuit including the terminal T2, the switch S, motor 35, and the terminal T1. Due to the extremely fast switching operation of the silicon gated switch, the motor 35 is energized at substantially the particular instant during a half cycle of the power supply that the control electrode 44 receives a pulse. Accordingly, the speed of operation of the motor 35 may be continuously varied i.e. infinitely varied, according to the time in a half cycle of the power supply at which the control electrode 44 receives a switch operating pulse.

The signal pulses are provided to the control electrode 44 by circuitry 45 which is connected between the terminals T1, T2 through a full wave rectifier CR including diodes D1, D2 which cooperate to provide the circuitry 45 with full wave rectified unfiltered current across junctions 50, 51. During a positive half cycle of the power supply the circuitry 45 is energized through a circuit which may be traced from the terminal T1 through the junction 50, a voltage dropping resistor R1, a junction 52, elements of a circuitry 45, to be described presently, a junction 53, the diode D2, the junction 51, and to the terminal T2. During a negative half cycle of the power supply, energizing current for the circuitry 45 is provided from the terminal T2 through the junction 51, a voltage dropping resistor R2, the junction 52, the elements of the control circuitry 45, the junction 53, the diode D1, junction 50, and to the terminal T1. From the foregoing de-

scription it is apparent that the voltage dropping resistors R1, R2 define a voltage dividing network connected across the terminals T1, T2 to provide a controlled instantaneous voltage level at the junction 52 which is proportional to the voltage level across the terminals T1, T2.

The circuit 45 includes a differential amplifier comprised of PNP transistors Q1, Q2 and a triggering circuit defined by the transistor Q2 and an NPN transistor Q3, which triggering circuit is effective to cause the switch S to be rendered conductive at a particular instant during a half cycle of the power supply depending upon sensed cooling capacity of the refrigerated air circulated in the display cabinet 10. More particularly, the triggering circuit is coupled to the control electrode 44 of the switch S through a pulse transformer 57 having a primary winding 58 inducing a current pulse in the secondary winding 60 which is connected to the control electrode 44 of the switch S. When the triggering circuit is rendered conductive, current flow is initiated primary winding 58 including a current pulse in the secondary winding 60 which provides a positive pulse to the control electrode 44 of the switch S to render that switch conductive.

The transistors Q1, Q2 include emitter-base circuits which are connected to the junction 52 through a junction 61, resistor R3 and a junction 62. The emitter-base circuit for the transistor Q1 may be traced from the junction 62 through the emitter electrode 63 of the transistor Q1, base electrode 64, wiper 65 of the potentiometer R4, a resistor R5, junction 66 and to a negative terminal of the power supply through the rectifier CR. The emitter-base circuit for the transistor Q2 may be traced from the junction 62 through the emitter electrode 70 of the transistor Q2, base electrode 71, a junction 72, junction 73, a resistor R6, and to a negative terminal of the power supply through the rectifier CR.

The base electrodes 64, 71 of the transistors Q1, Q2 are connected into separate arms of a bridge circuit having a first arm which is traced from the junction 52 to a junction 74, the junction 61, a variable resistor R7 in the form of a thermistor, the potentiometer R4, resistor R5 and through the rectifier CR to the negative terminal of the power supply. The other arm of the bridge is connected from the junction 52 through the junction 74, a resistor R8, the junction 73, resistor R6, and through the rectifier CR to the negative terminal of the power supply.

Since the resistors R8, R6 are fixed resistors the instantaneous voltage at the junction 73 connected to the base electrode 71 of the transistor Q2 is maintained at a substantially fixed percentage of the voltage across the junctions 52, 53 of the circuitry 45. The leg of the bridge including the resistors R7, R5, and potentiometer R4, produces an instantaneous voltage level at the wiper 65 of the potentiometer R4 connected to the base electrode 64 of Q1, which varies as a percentage of the voltage level across the junctions 52, 53 depending upon the resistance of the variable resistor R7. Accordingly, the time in any half cycle of the power supply at which the transistor Q1 is rendered conductive may be varied relative to the time during the half cycle when the transistor Q2 is conductive in accordance with variations in the resistance of the resistor R7.

When the resistance of the resistor R7 is relatively high, for example, the voltage level at the wiper 65 of the potentiometer R4 is relatively low and the emitter-base circuit of the transistor Q1 is rendered conductive relatively early in a half cycle of the power supply to establish an emitter-collector circuit in that transistor which may be traced from the junction 62 to the emitter 63 and collector 77 of the transistor Q1, a resistor R9, junction 80 and through the rectifier CR to the negative terminal of the power supply. When the transistor Q1 is rendered conductive the rise in voltage level at the junction 62 is retarded according to conduction through the transistor Q1, i.e. when the transistor Q1 is highly conductive the instantaneous voltage level at the junction 62

is relatively low, while low conductivity of the transistor Q1 produces a correspondingly higher voltage level at the junction 62.

When the voltage level at the junction 62 is sufficiently high relative to the voltage level provided at the base 71 of the transistor Q2, that transistor is rendered conductive to establish an emitter-collector circuit for that transistor which may be traced from the junction 62 through the emitter 70 and collector 81 of the transistor Q2, a junction 82, resistor R10, junction 83, and to the negative terminal of the power supply through the rectifier CR.

The transistor Q2 is regeneratively interconnected with the transistor Q3 to define the triggering circuit referred to and when the transistor Q2 is initially rendered conductive a base-emitter circuit for the transistor Q3 is established from the junction 62 through the emitter-collector circuit of the transistor Q2, the junction 82, base 84 and emitter 85 of the transistor Q3, primary winding 58 of the pulse transformer 57, a junction 86, and to the negative terminal of the power supply through the rectifier CR. It will be appreciated that the resistor R10 provides a voltage level at the junction 82 which is sufficiently high to establish the base-emitter circuit of the transistor Q3 as described.

When the base-emitter circuit of the transistor Q3 is established, the collector-emitter circuit of that transistor is established from the junction 62 through the emitter 70 and the base 71 of the transistor Q2, junction 72, collector 87, and emitter 85 of the transistor Q3, the primary winding 58 and a junction 86. Conduction in the collector-emitter circuit of the transistor Q3 reduces the voltage level at the base 71 of the transistor Q2 which renders the transistor Q2 fully conductive, in turn rendering the transistor Q3 fully conductive in a regenerative manner. Thus when the transistor Q2 is initially rendered conductive the transistor Q3 is substantially instantaneously fully conductive to produce a low impedance circuit from the junction 82 through the primary winding 58 of the pulse transformer 57 and to the junction 86.

It should be appreciated from the foregoing that the instant in a particular half cycle at which the transistor Q2 is rendered conductive is controlled by conduction of the transistor Q1 which in turn is controlled by the impedance of the resistor R7. For example, when the resistance of the resistor R7 is relatively low, the voltage level at the base 64 of the transistor Q1 is relatively high, causing the emitter-collector impedance of the transistor Q1 to remain relatively high during a half cycle of the power supply and thus providing a voltage level at the junction 62 which renders the transistors Q2, Q3 conductive relatively early in a half cycle. Conversely when the impedance of the resistor R7 is relatively large the transistor Q1 is conductive relatively early in each half cycle causing the instantaneous voltage level at the junction 62 to be relatively low and retards conduction of the transistors Q2, Q3 in the half cycle. As a result of the noted cooperation of the transistors Q1, Q2 when the impedance of the resistor R7 is high the switch S is rendered conductive relatively late in a half cycle of the power supply and power supplied to the motor 35 is relatively small, causing a low fan speed. When the impedance of the resistor R7 is low, the switch S is rendered conductive early in each half cycle and the power supplied to the motor is increased, increasing the fan speed.

A charging circuit is associated with the triggering circuit for providing current spike through the primary winding of the transformer 57 when the trigger circuit is conductive. The charging circuit includes the resistor R3 and a capacitor C1 connected in series between the junction 61 and a junction 90, at the voltage of the negative terminal of the power supply. As the voltage rises at the junction 61 during each half cycle of the power supply the capacitor C1 is charged through the resistor R3, and when the transistor Q2 is rendered conductive in the manner described, the capacitor C1 discharges through the

low impedance path provided by the transistors Q2, Q3, and the primary winding 56 of the pulse transformer 57, through the junctions 86, 83, 90. Thus the capacitor C1 provides a current pulse or spike through the primary winding 56 of the pulse transformer 57 when the transistors Q2, Q3, are rendered conductive to render the switch S conductive at a particular time in the half cycle of the power supply determined by the impedance of the resistor R7. The capacitor C1 additionally provides a phase lag at the emitter of transistor Q2 so that the triggering pulse is provided at the appropriate phase angle as determined by the sensed cooling capacity.

The resistor R7 is preferably a thermistor which is disposed in the duct 37 of the display case 10 in heat transfer relationship with refrigerated air circulating in the duct 37. FIG. 3 illustrates a support member 100 for the thermistor R7 including a body portion 101 which is adapted to be fastened to the cabinet 11 of the display device 10 suitable fasteners such as screws 102, and tubular member 103 formed intricately with the body 101 and disposed in the stream of refrigerated air flowing through the duct 37.

The tubular member 103 defines a bore 104 extending longitudinally therethrough having an enlarged bore portion 105 in which the thermistor R7 is supported at the upstream end of the tubular member 103. It is apparent from FIG. 3 that the bore 104 has an axis which extends generally parallel to the direction of flow of air in the duct 37. The thermistor R7 is supported centrally of the enlarged bore portion 105 by conductors 106, 107 by which the thermistor R7 is connected into the circuit 45 as described previously. The conductors 106, 107 are nested in a generally Y-shaped opening 110 extending from the base to the body portion 101 to the enlarged bore portion 105. In the preferred embodiment the member 100 is preferably a two piece construction of molded plastic material which pieces are joined along a plane through the axis of the bore 104.

Current flow through the thermistor R7 is such that it is self heated to a temperature about 10-15° F. above that of the refrigerated air flowing through the bore 104. The air flowing through the bore 104 carries heat away from the thermistor at a rate which is determined by the temperature and velocity of the air flowing in the bore 104. If the temperature of the refrigerated air increases due to frost accumulation on the heat exchanger the heat dissipated from the thermistor is reduced, causing an increase in the temperature of the thermistor to produce a signal to the circuitry 45 which increases the speed of the blower motor. Increased blower speed increases the velocity of the air flowing over the thermistor to stabilize the rate of heat dissipation therefrom.

From the foregoing description it should be appreciated that the change in air velocity resulting from a change in speed of the induction motor 34 provides what may be termed feedback to the circuit 45 so that the velocity of air in the air duct sensed by the thermistor R7 tends to be maintained at an optimum magnitude for a given amount of frost accumulation on the heat exchanger, i.e. the air velocity increases only by an amount necessary to stabilize the temperature of the thermistor R7 and establish a resistance which corresponds to a particular frost condition of the heat exchanger. The wiper 65 of the potentiometer R4 is suitably connected to a control knob (not shown) so that instantaneous voltage level at the base 64 of the transistor Q1 may be varied according to the position of the wiper 65. Accordingly, a particular desired velocity range of air in the duct 37 can be established over a refrigeration cycle by manually setting the wiper 65 of the potentiometer R4.

It should also be noted that if frost accumulation on the heat exchanger throttles the air flow thereacross, the rate of heat dissipation from the thermistor is reduced and will cause a corresponding increase in fan speed to maximize the air velocity and cooling capacity of the air cur-

tain under circumstances wherein the heat exchanger is heavily laden with frost.

FIG. 4 illustrates a modified control apparatus embodying the present invention wherein the blower switch S and circuitry 45, with the exception of the resistor R5 and thermistor R7, are identical to those described in reference to FIG. 2 and are designated by the same reference characters. The modified control apparatus includes a signal circuit assembly 120 for providing a modulated velocity signal to the circuitry 45 and which assembly is connected directly across the terminals T1, T2. The circuitry 120 includes a voltage dropping capacitor C2 connected in series with a selfheated thermistor R15 and incandescent lamp 121 between junctions 122, 123 connected across the terminals T1, T2 of the power supply. The circuitry 120 additionally includes a light responsive resistor R16 which is positioned adjacent the lamp 121 and connected into the control circuitry 45 at points corresponding to the points of connection of the resistor R5 referred to previously. The thermistor R7 is replaced, in the FIG. 4 embodiment, by a suitable fixed resistance element, not shown.

The thermistor R15 is disposed in the duct 37 in heat exchange relationship with refrigerated air flowing through the duct in the same manner as the thermistor R7 described in reference to FIGS. 2 and 3 and is connected in parallel with the bulb 121 so that as the resistance of the thermistor 115 is reduced (i.e. as the thermistor temperature increases,) the intensity of the light produced by the bulb 121 is decreased. The capacitor C2 isolates the bulb 121 and thermistor R15 from normal line voltage fluctuations across the terminals T1, T2 in addition to dropping the voltage across the parallel connected lamp 121 and thermistor R15 to suitable levels.

The light responsive resistance element R16, due to its position adjacent the bulb 121, produces a resistance in the arm of the bridge connected to the transistor Q1 which varies in response to variations of intensity of light from the bulb 121. Accordingly, when the temperature of the thermistor R15 is increased due to an increase in temperature of the air flowing thereacross the resistance of the thermistor R15 is reduced, causing a reduction in the intensity of light from the bulb 121. The reduced light intensity increases the resistance of the light responsive resistor R16, causing the speed of the fan motor 35 to increase as described above. The increased fan speed increases the velocity of the air flow across the thermistor by an amount which is just sufficient to stabilize the heat loss from the thermistor R15 to establish a somewhat higher temperature thereof corresponding to the particular frost conditions of the heat exchanger.

The circuitry 120 therefore provides for a velocity sensing arrangement which is protected from line voltage fluctuations of the power supply and which additionally provides a modulated signal to the fan speed control circuitry resulting in smoother responses of fan speed to sensed cooling capacity variations.

While two embodiments of the present invention have been illustrated and described herein in considerable detail, the present invention is not to be considered to be limited to the precise constructions shown. It is my intention to cover hereby all adaptations, modifications and uses of the invention which come within the scope of the appended claims.

I claim:

1. A refrigerated display case for reception of articles to be maintained at subfreezing temperatures comprising a cabinet defining an article receiving compartment open at a side, ducts for directing a curtain of air across said open side of said compartment, an air cooling heat exchanger associated with said cabinet and communicating with said ducts, electrically energized means operable to propel air at variable flow rate in a path across said heat exchanger and in a curtain across said open side of said chamber after which it is returned to said exchanger, and

control means to vary the flow rate of said air in said path in response to variation in the cooling capacity of said air curtain including sensing apparatus for producing a control signal which varies as a function of air velocity in said air circuit.

2. A display case as defined in claim 1 wherein said sensing apparatus includes a self heated resistance element having an electrical resistance which varies in accordance with changes in its temperature, said control means being operable to continuously vary the speed of said blower means in response to signals produced by said sensing apparatus.

3. A display case as defined in claim 1 wherein said control means includes a semiconductor switch connected in circuit with said blower means and effective to control the amount of electrical power supplied to said blower in response to signals from said sensing apparatus.

4. A display case as defined in claim 1 wherein said sensing apparatus includes a resistance element sensitive to changes in velocity of said air curtain, a light source coupled to said resistance element for producing light having an intensity which varies in response to resistance of said element and a light sensitive impedance element exposed to light from said source and connected into said control circuitry to produce said control signal.

5. A display case as defined in claim 4 wherein said light source and said resistance element are connected in parallel.

6. A display case as defined in claim 4 wherein said resistance element is a thermistor, and further including a support for said thermistor connected to said case in a duct, said support defining an air passage in which said thermistor is disposed in heat exchange relation with air in said passage.

7. A refrigerated display case for reception of articles to be maintained at subfreezing temperatures comprising a cabinet defining an article receiving compartment; air ducts, an air cooling heat exchanger supported in said cabinet, electrically energized blower means for directing air in a circuit across said heat exchanger through said ducts and in a curtain across an open side of said compartment, and control apparatus modulating the velocity of said air curtain in response to sensed changes in cooling capacity of air in said circuit so that said air curtain cooling capacity is maintained at an optimum level for a given amount of frost on said heat exchanger.

8. A display case as defined in claim 7 wherein said control apparatus includes sensing means for detecting changes in cooling capacity of said air and providing a control signal, and an electrical element for varying the speed of operation of said blower in an infinite manner in response to said control signal.

9. In a refrigerated display case having a refrigerated product receiving chamber with an open side; a refrigeration system including an air cooling heat exchanger maintained at temperatures below the freezing point of water, electrically energized blower means for propelling a flow of air over said heat exchanger and in a curtain across said open side of said chamber, and control means for varying the flow rate of air across said heat exchanger in response to sensed cooling capacity of air flowing to said air curtain so that the rate of heat transfer from said air to said heat exchanger is maintained relatively constant as frost accumulates on said heat exchanger.

10. In a refrigerated display case as defined in claim 9 wherein said control means includes a thermally responsive self-heated resistance element disposed in heat transfer relationship to a flow of refrigerated air and producing a control signal in response to a variation in said heat transfer relationship with said air and semiconductor switch means connected for controlling said blower means and responsive to said control signal to effect a change in the flow rate of said air across said heat exchanger in proportion to the change in heat transfer relationship between said air and said resistance element.

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11. A refrigerated display case as defined in claim 10 wherein said resistance element is connected across a power supply in parallel with an electrically energized light source, and further including a light responsive element exposed to light from said source, said light source varying in intensity in proportion to said change in heat transfer relationship and effecting a change in impedance of said light responsive element, said semiconductor switch means connected in a circuit with said light responsive element and operative to vary the power supplied to said blower means as the impedance of said light responsive element varies.

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WILLIAM J. WYE, *Primary Examiner.*

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