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Kramer

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[54] **REFRIGERATION SYSTEMS INCLUDING EVAPORATOR WITH 2 SPEED FAN MOTOR**

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[52] **U.S. Cl.** **62/180;** 62/181; 62/186; 62/183

[51] **Int. Cl.** **F25d 17/00**

[58] **Field of Search** 62/180, 186, 181, 183

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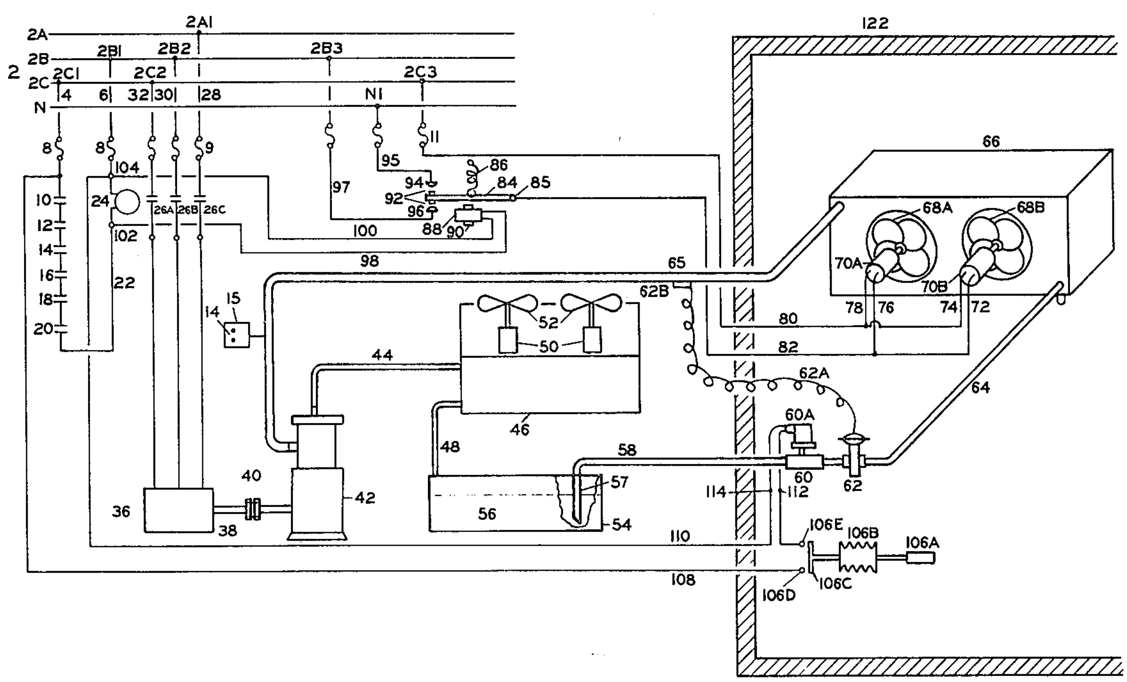
[57] **ABSTRACT**

A refrigeration system having a compressor driven by a motor having a control for turning it on and off, and an evaporator which includes a motor driven fan where the fan motor can operate at high speed or at low speed, and where the fan motor is connected to operate at high speed when the compressor motor is on and to operate at low speed when the compressor motor is off.

1 Claim, 5 Drawing Figures



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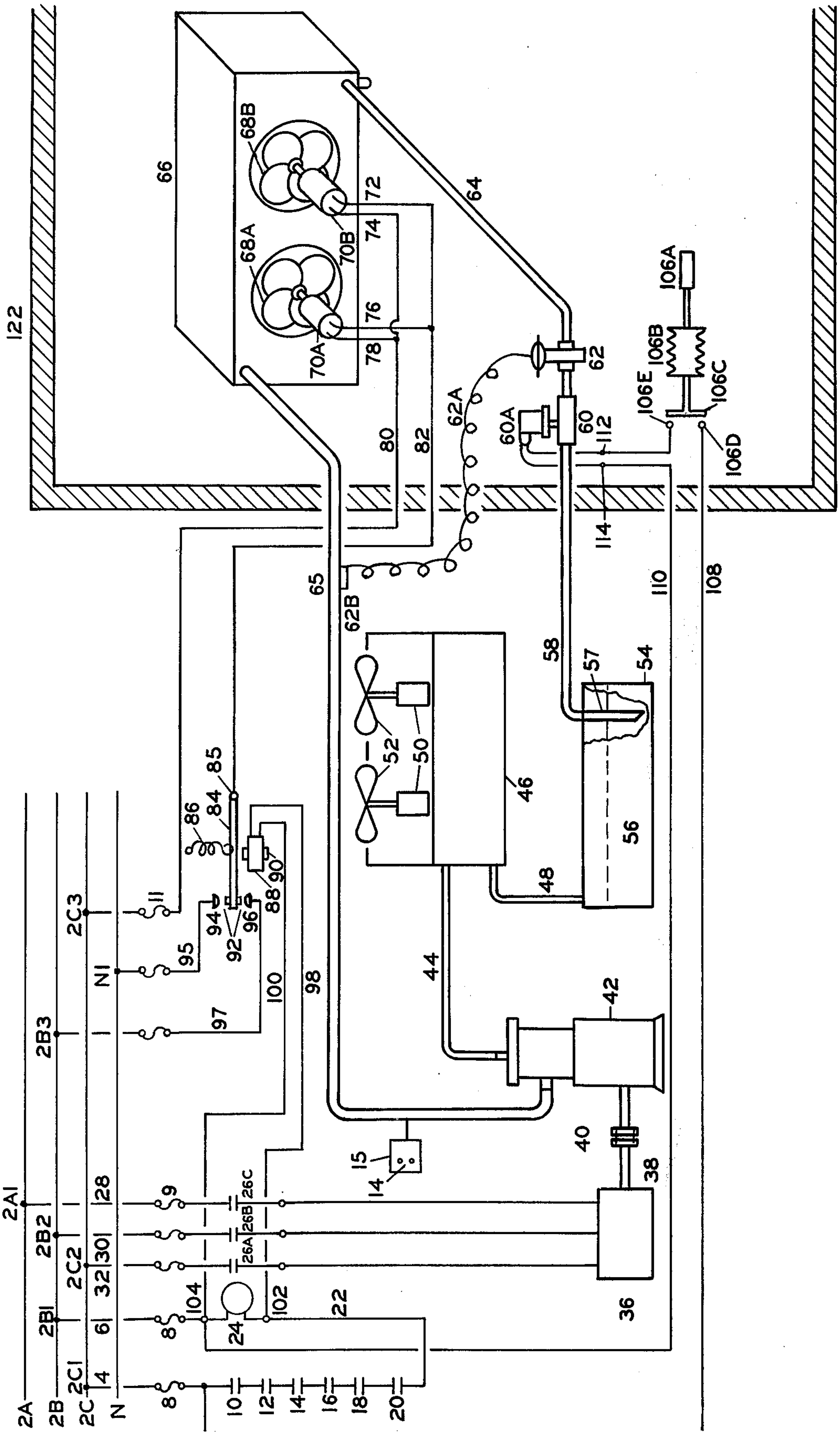

FIG. 1.

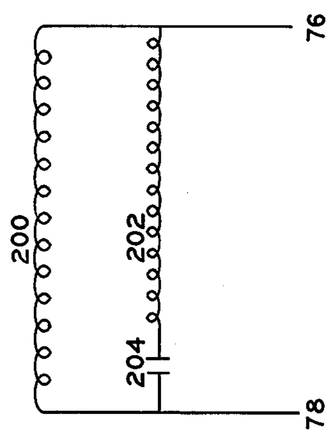

FIG. 3.

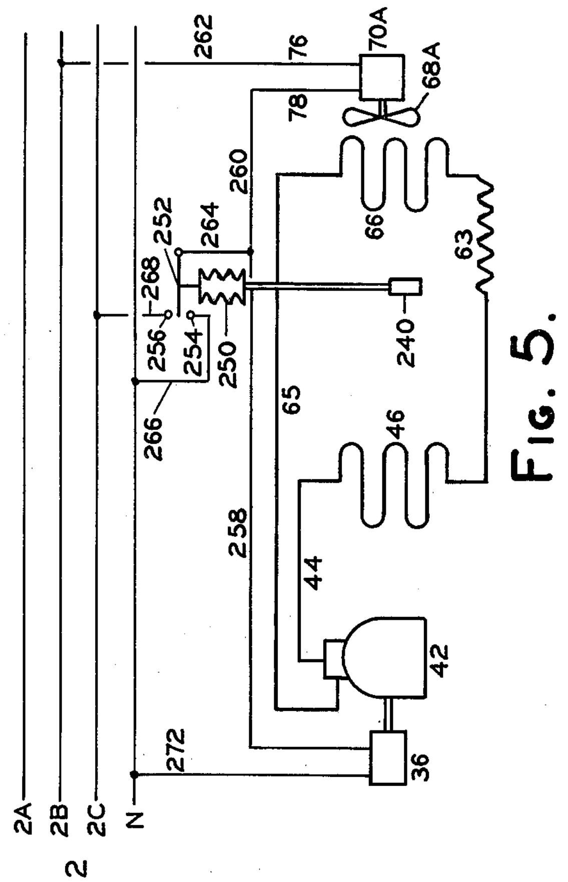

FIG. 5.

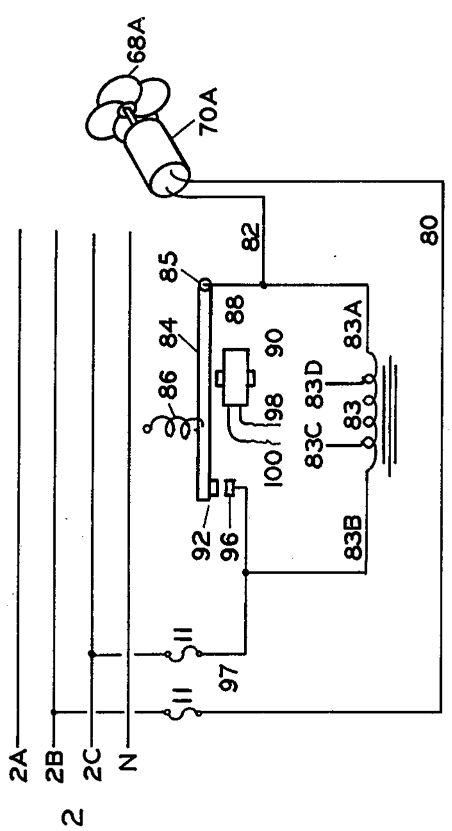

FIG. 2.

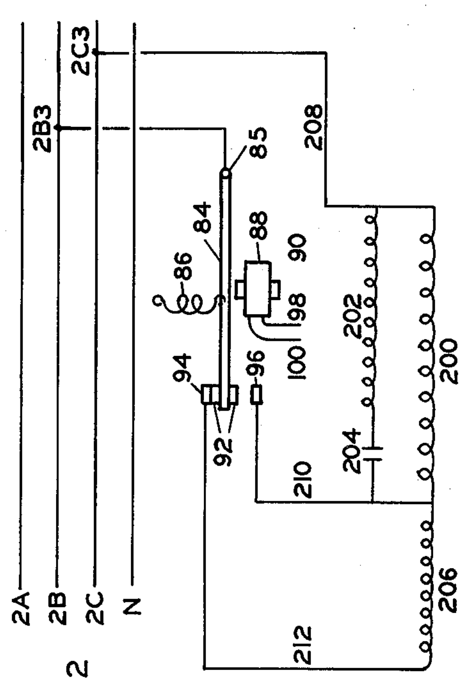

FIG. 4.

REFRIGERATION SYSTEMS INCLUDING EVAPORATOR WITH 2 SPEED FAN MOTOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to refrigeration systems with evaporators which cool air forced over them by motor driven fans, and especially to power savings that result during periods that the compressor is not in operation when the speed and therefore the power input to the evaporator fan motor is sharply reduced by means set forth herein.

2. Description of the Prior Art

Refrigeration systems employing evaporators having motors which drive fans for the purpose of drawing or blowing air over the evaporator for the purpose of cooling that air well known. It is currently normal practice, when refrigeration evaporators are applied to cooler or freezer boxes, to leave fan motors on the evaporators running at full speed whether the compressor is in operation or not. On medium temperature systems, that is, those systems operating to cool rooms to between 45° and 32°, the practice of leaving the evaporator fans running has some basis because the frost that is deposited on the surfaces of the refrigerating coil during those periods that the compressor is operating is defrosted by the passage of air warmer than 32° during those periods when the compressor is not operating.

BRIEF SUMMARY OF THE INVENTION

The invention is an improvement in the design of refrigeration systems employing air cooling evaporators which use motors to drive the air over the evaporator surfaces. It is known that motors utilize less energy when running at low speed than at high speed. With the recent shortage of electrical energy caused by widespread, and increasing shortage of the fossil fuels used to generate electricity, increasing thought has been given to improvements in refrigeration machinery that would provide the same cooling but at a lower power cost.

This invention relates to the reduction in overall power consumption for the systems required to refrigerate a cooler or freezer where the evaporators are equipped with motors for driving their fans which are capable of operating at full speed while consuming full power and at lower speed while consuming less power. This invention is directed toward a refrigeration system with an evaporator using motors capable of operating at higher and lower speeds, and the control arrangement whereby the motors driving the evaporator fans operate at higher speed during those periods that the compressor is on where full air flow is necessary in order to achieve full cooling effect, and lower speed when the compressor is off with consequent reduction in the power that the fan motors consume those periods when the compressor is off. In this specification "compressor on" means that the motor driving the compressor is energized; and "compressor off" means that the motor driving the compressor is de-energized. In those systems where the passage of air over the evaporator is required, during compressor off cycles, for the purpose of defrosting the deposited frost, a time delay switch or timer must be provided to allow the evaporator fans to continue their full speed operation for the period immediately following the beginning of the compressor off-cycle that defrost would normally required. Then if the compressor off-cycle is extended beyond the period required for the normal defrost of the evaporator, the timer will cause the evaporator fan motor to be reconnected for low speed operation for the remainder of the compressor off-cycle which in fact may be of great duration, with consequent power savings.

It is important to notice here, the power savings which result from reduction of power input to the fan motors is only part of the power savings which occur to the user of the invention. The power input to the fan motors is part of the total heat input to the refrigerated space. The total compressor operating time must be sufficient to remove all the heat that has leaked into or been put into the cooler or freezer. The longer the operating time of the evaporator fan motors at full power, the longer some of the compressors must run in order to remove that heat. In a system maintaining a box at −10°F every reduction of one watt in heat input to the box results in a power saving at the compressor of approximately 1 watt so that twice the number of watts saved at the evaporator are saved totally. It generally has been considered unwise to turn off the evaporator fan motors completely in freezers because the grease in the motor bearings has a tendency to harden. On restarting, the hardened grease lubricates poorly until it softens, which shortens bearing life, and because a stagnant air condition in the box may arise which generates uneven temperature conditions and, therefore, poor keeping qualities of the merchandise stored within the cooler or freezer. However, the high air flow which is required by evaporators for efficient heat transfer performance is not generally required by the refrigerator itself for the distribution of the coil air produced by these evaporators. In general, a much lesser air flow and air velocity is required for distribution of the cold air than is required for efficient operation of the evaporator. Therefore, the operation of the evaporator fans at speeds less than full, for instance at one-half speed, during those periods when the compressor is not operating, is entirely consistant with good refrigeration practice.

The speed change of the evaporator fan motors may be related to the on or off condition of the compressor; or the speed of the motors may instead be related to the condition of the initiating control (contactor; starter or switch; timer; temperature control; pressure control; or other). However, the relationship need not require instantaneous correspondence of conditions. Substantial delay in change of motor speed after change in control or compressor condition would still lie within the intent of the claims.

Techniques used for changing the speed of the fan motors could be: (a) the use of a motor which was inherently designed for single voltage operation but was usable at either of two speeds, depending on the connections made to its leads; (b) a motor which would operate at higher speed if a high voltage was applied to its terminals, and a lower speed if a low voltage was applied to its terminals; (b–1) the variation where the lower voltage was achieved by connecting in series with the power line to the motor an impedance, that is, a resistance or a reactance such as a capacitance or inductance, which served to lower the voltage delivered to the motor below that of the supply line; or (b–2) where two different voltage supply lines were available, connecting the motor leads alternately to the higher voltage line and to the lower voltage line, in accord with the principles enumerated in this specification.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a compression type refrigeration system cooling an insulated space using an electric motor driven compressor, a condenser, and an evaporator within the insulated space. The evaporator cools air blown over it by fans driven by motors capable of operating at high or low speed. The high or low speed conditions of the evaporator fan motors are determined by the position of a relay which serves to connect the evaporator fan motors to either a high voltage source or a low voltage source, depending on whether the compressor is operating or stationary.

FIG. 2 shows an modified electrical circuit for supplying high and low voltage power to evaporator fan motors, depending on the condition of a relay. When the relay is energized and its contacts are closed, high voltage power is delivered to the fan motor. When the relay coil is de-energized, then the relay contacts are open. The current supplied to the motor is forced to traverse a choke which causes the voltage supply to the motor to be reduced, and thereupon to operate at a lower speed than when its supply of electricity came un-interruptedly from the electric supply means.

FIG. 3 shows the circuit diagram of a permanent split capacitor motor which is one of the types that are in general suitable for high voltage - high speed; low voltage - low speed operation of the type that is described in this specification, and in general is usable in the circuits and arrangements of FIGS. 1 & 2.

FIG. 4 shows a combined internal motor wiring diagram and a relay and power supply arrangement which includes a typical wiring diagram for a two speed motor, including an extended or tapped main winding and a relay which selects the low speed tap or lead of the motor when the relay is de-engerized and the high speed tap of the motor when the relay is energized.

FIG. 5 shows a simplified control arrangement utilizing a thermostat with a double throw contact which controls the ON/OFF operation of the compressor and simultaneously controls the evaporator motor voltage so that when the compressor is "ON" the evaporator motor is connected to "high" voltage and runs at high speed, and when the compressor is "OFF" the evaporator motor is connected to low voltage and runs at low speed.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 shows compressor **42** driven by motor **36** by way of shaft **38** and coupling **40.** The compressor receives refrigerant vapor from suction line **65,** and after compressing it to a pressure sufficiently high to condense in the condenser, discharges it to condenser coil **46** by discharge line **44.** There it is condensed to a liquid by the cooling effect of the air which is drawn over the condenser coil **46** by fans **52** driven by motors **50.** The liquid, resulting from the condensation of the refrigerant, flows through conduit **48** to receiver **54,** wherein it collects as a pool **56.** As needed this liquid refrigerant is delivered to the expansion valve **62** by way of dip tube **57** liquid line **58** and liquid line solenoid **60.** The open or closed condition of liquid solenoid **60** is determined by the condition of energization or de-energization of its coil **60A.**

The operation of the system to refrigerate or stop refrigerating is related to the open or closed condition of liquid solenoid valve **60** which condition is determined by thermostat **106** which monitors the temperature of the cooled space and turns on the system when the space gets warmer than desired. Sensing bulb **106A** is in the cooled space. Bellows **106B** expands as the bulb becomes warmer. The expansion of the bellows causes conducting bar **106C** to make electrical contact between terminals **106D** and **106E.** When contacts **106D** and **106E** are made, solenoid coil **60A** is energized, causing solenoid valve **60** to open. Conversely, the cooling of bulb **106A** below its setting point causes bar **106C** to move away from contacts **106D** and **106E,** opening the circuit which supplies electricity to solenoid coil **60A** causing solenoid coil **60A** to become deenergized. This immediately results in solenoid **60** closing, preventing any further refrigerant liquid flow to the evaporator **66** from the receiver **54.**

During the period that solenoid valve **60** is open refrigerant liquid from receiver **54** flows to evaporator **66** with its temperature and pressure reduced to the point where its refrigerating effect can be applied to the heat transfer element of the evaporator **66,** because of the restricting effect of the expansion valve **62.** In the heat transfer element of evaporator **66,** the liquid refrigerant which has been supplied to it is evaporated to a vapor with its latent heat of evaporation supplied by the air blown across the heat transfer element by the fan **68A** and **68B,** which are driven by the motors **70A** and **70B** respectively. The heat supplied from the air blown by the fans serves to cool the air for the overall effect of cooling the insulated space whose boundaries are established by insulated wall **122.** When the refrigerant liquid supplied to the evaporator **66** has been completely evaporated, the resulting vapor is returned to the compressor **42** via suction line **65.** In its return path, the cool vapor has its temperature monitored by bulb **62B** of the expansion valve **62.** If the vapor becomes too cool, which condition might result from expansion valve **62** being open more than necessary, resulting in a flow of liquid refrigerant through expansion valve **62** to the evaporator **66,** which is more than the evaporator can evaporate, the over-cooled bulb **62B** causes the valve elements to throttle the flow of refrigerant liquid to the evaporator **66.**

Compressor **36** is supplied with power from three phase, four wire, alternating current network **2,** comprising lines **2A, 2B, 2C** and **N** and in between any pair of **2A, 2B** and **2C** is a uniform alternating current single phase voltage whose phase differs from any other pair by 120°. The voltage from any one of lines **2A, 2B** or **2C** to the neutral line **N** is equal to the value of the voltage between the lines **2A, 2B** or **2C** or any of a pair of them divided by 1.732 ($\sqrt{3}$). For example, if power source **2** was a 208 volt three phase four wire network, the voltage between **2A** or **2B** and the voltage between **2B** and **2C,** and the voltage between **2C** and **2A** would be 208 volts, but the voltage between **2C** and **N** and the voltage between **2B** and **N** and the voltage **2A** and **N** would be 208 volts divided by 1.732 (eg. $\sqrt{3}$) or 120 volts.

Motor **38** can be supplied with power only if the contactor whose contacts **26A, 26B** and **26C** control the flow of electricity from the power supply lines to the motor are closed. The condition of the contacts is determined by the energized or de-energized condition of the contactor coil **24**.

The control circuit supplies power to the contactor coil (**24**) through leads **4** and **6** which connect to power lines **2B** and **2C** at points **2Cl** and **2Bl**. The control circuit for contactor magnetic coil **24** comprises supply line **6**, fuse **8**, wire **22** and control circuit contacts **20**, 18, 16, 14, 12, 10 and supply line **4**. The control contacts **10** through **20** comprise switches including manual on-off switch **10**, high pressure switch **12**, low pressure switch **14**, oil safety switch **16**, motor winding temperature thermostat **18**, motor current overload protector **20**.

Specifically, the portion of the system related to the operation of the invention is as follows:

When the insulated room **122** is cold, thermostat contacts **106D** and **106E** are open. As a result, the solenoid coil **60A** is de-energized and the solenoid **60** is closed. In this condition, the compressor **42** operates to pump vapor out of suction line **65** and the evaporator **66** until the pressure therein drops to the setting of the low pressure switch **15** whose contacts **14** are in the control circuit of the compressor contactor. Then, the contacts **14** of the pressure switch open, de-energizing coil **24** of the compressor contactor causing its contacts **26A**, **26B** and **26C** to open, stopping the compressor. At the same time power is removed from contactor coil **24**, power is also removed from relay coil **88**. When this coil is de-energized, spring **86** urges clapper **84** upward so that contact **92** mates with and creates an electrical connection with stationary contact **94** establishing an electrical circuit for the flow of electricity between neutral wire N at terminal point **N1** and power wire **2C** at connection point **2C3**. These connections provide a voltage for the operation of fan motors **70A** and **70B** of 120V, roughly half of the normal **208V** which is supplied to them for their full speed operation. At this reduced voltage, which is applied only when the compressor is stopped, the fans operate at essentially half speed and utilize essentially half the normal power.

As the temperature of the enclosed insulated space **122** gradually rises, the thermostat bulb **106A** reacts by increasing the pressure in bellows **106B**, forcing platen **106C** against contacts **106D** and **106E**, closing the circuit which allows electricity to be supplied to liquid solenoid coil **60A**. When the contact is complete and power is supplied to solenoid coil **60A**, liquid solenoid **60** opens, supplying refrigerant liquid from the receiver **54** through the expansion valve **62** to the evaporator **66**, as described before. As the liquid reaches the evaporator, some of it flashes to vapor, raising the pressure in the evaporator and in the connecting suction pipe **65** which communicates with pressure switch **15**. The pressure switch **15** senses the rise in pressure in the low side and when the rise is sufficient to reach its setting, contacts **14** close, supplying power to the compressor contactor coil **24** which causes the contacts **26A**, **26B** and **26C** to close. Simultaneously with the energization of contactor coil **24**, relay coil **88** is energized, which causes platen **84** to be attracted to magnet core **90** with a force greater than can be resisted by return spring **86**. The result of this motion is that the electrical circuit which had been formed between contacts **92** and **94** is now broken and a new electrical contact between contacts **92** and **96** is now made. This new electrical contact establishes a circuit between power wire **2B** and connection point **2B3** and power wire **2C** and connection point **2C3**. Since the potential between these two wires is 220V, the voltage applied to motors **70A** and **70B** now is 220V. It should be clear from the above description, therefore, that whenever compressor motor **36** is energized, causing the compressor to operate, evaporator fans **70A** and **70B** will be energized with high voltage electricity, and when the compressor motor **36** is de-energized, causing it to stop, evaporator fan motors **70A** and **70B** will be energized with low voltage electricity, causing them to run at approximately half speed with the significant power savings already described.

FIG. 2 shows one of the two evaporator fan motors, **70A**, shown in FIG. **1**, and a similar relay with a coil **88** with two wire leads **98** and **100**, which are intended to be connected at points **102** & **104** on the leads to the compressor contactor **24**, (FIG. **1**). It is clear, therefore, that coil **88** will be energized when compressor contactor coil **24** is energized and will be de-energized when compressor contactor coil **24** is de-energized. During energized condition, power will be supplied directly to evaporator fan motor **70A** from power wires **2B** and **2C** allowing their full voltage to be imposed directly on the windings of the fan motor **70A**. When the compressor stops and relay coil **88** is de-energized, the return spring **86** pulls the armature **84** away from the magnetic core **90**, at the same time breaking the electrical circuit between contacts **92** and **96**. Now electricity from power wires **2B** and **2C** must traverse both the motor and a voltage dropping reactor **83** which has leads **83A** and **83B**. This reactor can be selected for any voltage drop which would meet the needs of the user. The larger the voltage drop, the slower the fan motor **70A** would operate, and the greater the power saving. The normal range of voltage reduction which the ordinary design engineer would select the reactor or choke **83** to produce, would be in the range of 25 to 60 percent of the full power supply voltage. In this case, reactor **83** has been selected to produce a voltage drop of approximately 50 percent so that the voltage on the motor **78** is 104V, a 50 percent reduction of the 208V, which is the potential across the power supply wires **2B** and **2C**. It is clear, then, from the description of the operation of this fan motor control circuit that, during those periods when the compressor operates, full voltage is applied to the evaporator fan motor for achieving full speed operation for maximum cooling effect. During those periods when the compressor is not operating, a reduced voltage, which is selectable in advance by the design engineer, is applied to the fan motor **70A** with consequent reduction in power consumption and fan motor speed. If desired, a tapped reactor could be employed as shown in FIG. **2**, where taps **83C** and **83D** are shown. The connection of wire **83A** from its present position at the end of the reactor to position **83D** would result in a reduced voltage drop and application, in turn, of the wire **83A** to tap **83C** would result in a still further reduction in the voltage drop which would be imposed on evaporator motor **70** during periods of compressor non-operation.

FIG. 3 shows the internal wiring diagram for a motor whose type is described as permanent split capacitor. This is a single phase alternating current motor which has no starting relay or starting switch but has a main winding **200**, a phase winding **202**, of a much higher resistance than the main winding, and a capacitor **204** in series with the phase winding. These components are designed and selected to produce the starting torque and operating speed and power for each application. These motors, in general have the characteristic that when reduced voltages are applied, reduced speeds and reduced power consumption occur. This is one of the motor types which can be employed as evaporator fan motor **70A**. Another type which can be so employed is the so-called shaded pole motor.

FIG. **4** shows the application of the concept of the invention to a motor designated as a two-speed type. This motor has a main winding **200** and an extended main winding **206**. In parallel across the main winding is the phase winding **202** in a series with its capacitor **204**. The relay with its coil **88**, with its leads **98** and **100**, is connected in exactly the same fasion as the relay coil with the same number in FIG. **1**. When the contactor coil **24** is energized, coil **88** is energized, attracting clapper **84** against the force of return spring **86**, so that contact **92** and contact **96** form an electrical circuit. In this mode, the motor operates at full speed in order to achieve full air flow and refrigerating effect at the evaporator. When the compressor contactor is de-energized, coil **88** is de-energized, and the return spring **86** draws clapper **84** upwards, breaking the circuit between contacts **92** and **96** and making the circuit between **92** and **94**. Application of the full line voltage to the extended winding **206** through lead **212** causes the motor to operate at a reduced speed, depending on the design of extended circuit **206**. In this case, the extended winding is selected to provide a motor speed and a motor power consumption of approximately one-half of that produced and consumed at the high speed condition.

In FIG. **5** the thermostat comprising bulb **240**, bellows **250**, contact arm **252**, cool contact **254**, and warm contact **256** is so connected that when the bulb is exposed to a temperature lower than its setting, the contact arm **252** makes electrical contact with contact **254** completing the electrical circuit from power upply wire 2B, wire **262**, motor lead **76**, motor **70A**, motor lead **78**, wire **260**, wire **264**, contact arm **252**, cool contact **254**, and wire **266** to neutral conductor N. The connection from wire 2B to N provides a low voltage power supply to motor **70A** which is designed for full speed operation at 208 volts but operates at lower speed at lower voltage. The motor **36** of the compressor, which is designed for full speed operation at 120 volts, has both leads connected to power supply wire N, one by wire **272**, the second by wires **258, 264,** contact carrier **252**, cool contact **254**, and wire **266**, and therefore does not run, having zero voltage across its leads. When the cooled space warms, the expandable fluid in bulb **240** causes the bellows **250** to move contact arm **252** in a direction which causes it to break contact with contact **254** and make contact with contact **256.** In this state, power supply wire 2C supplies power through wire **268**, contact **256** and contact arm **254** and wire **264** to wire **260** and to lead **78** of fan motor **70A**. The other lead **76** of the fan motor is connected to power supply wire 2B which in cooperation with supply wire 2C provides full voltage of **208** across the fan motor for its full speed operation. The compressor motor now has lead **272** as before connected to N. Its other lead **258** now is connected to power supply wire 2C by way of wire **264**, contact arm **252**, contact **256** and wire **268.** This provides 120 volts across the compressor motor, which causes it to operate normally. Thus, with one control and switch we have established on-off control of the compressor and corresponding high-low speed control of the evaporator fan.

I claim:

1. An improved refrigeration system having conduit connected compressor, condenser (**46**), restrictor (**62**), and evaporator (**66**); first motor (**36**) connected to the compressor for driving it, said first motor having energized and deenergized conditions; a fan (**68A**), positioned to blow air over the evaporator (**66**); a second motor (**70A**) connected to said fan for driving it, said second motor adapted to operate at higher voltage-higher speed, lower voltage-lower speed; first conductor means (**82**) connected to said second motor for supplying electric power to it; wherein the improvement comprises; second conductor means (**97**) adapted for connection to a higher voltage power supply (**2B3**); third impedance-free conductor means (**95**) adapted for connection to a lower voltage power supply (**N1**); switch means (**92, 94, 96**) connected to first conductor means (**82**), second conductor means (**97**) and third conductor means (**95**), adapted to provide electrical contact between said first conductor means (**82**) and alternately second conductor means (**97**) and third conductor means (**95**), said switch means (**92, 94, 96**) being operatively connected to establish essential correspondence between

a. the energized condition of the first motor (**36**) and the electrical contact between the first conductor means (**82**) and the second conductor means (**97**) to cause the second motor to operate at higher speed, and

b. the deenergized condition of the first motor (**36**) and electrical contact between the first conductor means (**82**) and the third conductor means (**95**) to cause the second motor to operate at lower speed.

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