

[54] CENTRIFUGAL HEAT PUMP WITH
OVERLOAD PROTECTION

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[58] Field of Search 62/158, 228, 230, 510, 196, 62/199, 200, DIG. 17, 180

[56]

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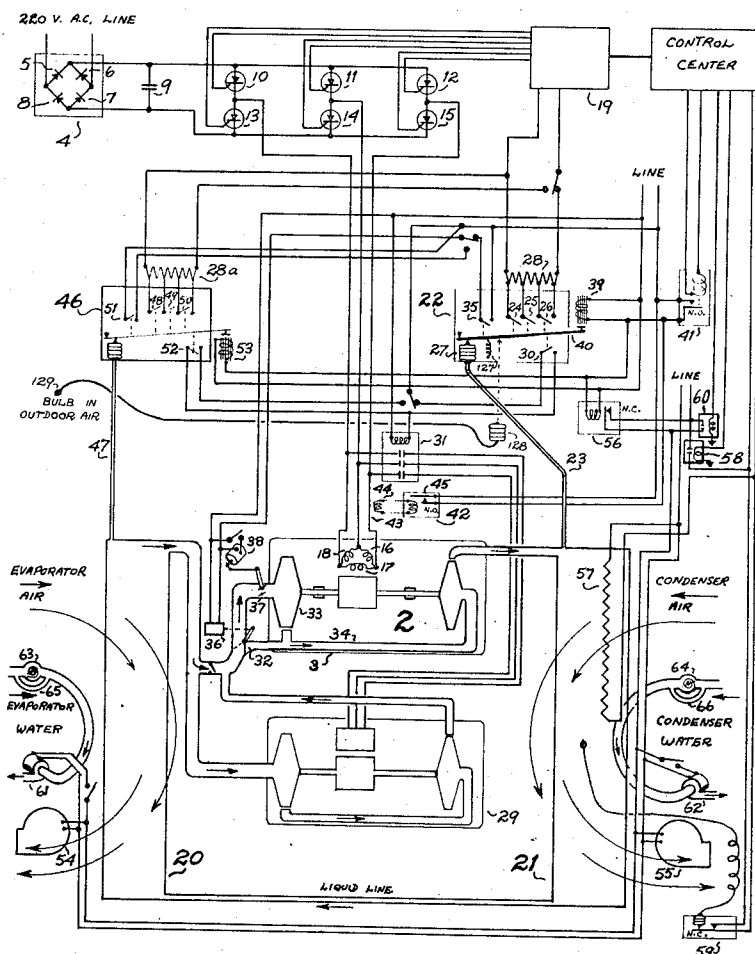
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[57]

ABSTRACT

A variable capacity air conditioning system for heat pump operation using small centrifugal compressors and including capacity reducing methods to prevent overloading when starting up the compressors, and including methods to remove the refrigerant liquid from the evaporator while the system is not in use, also to prevent overloading when restarting.

7 Claims, 7 Drawing Figures



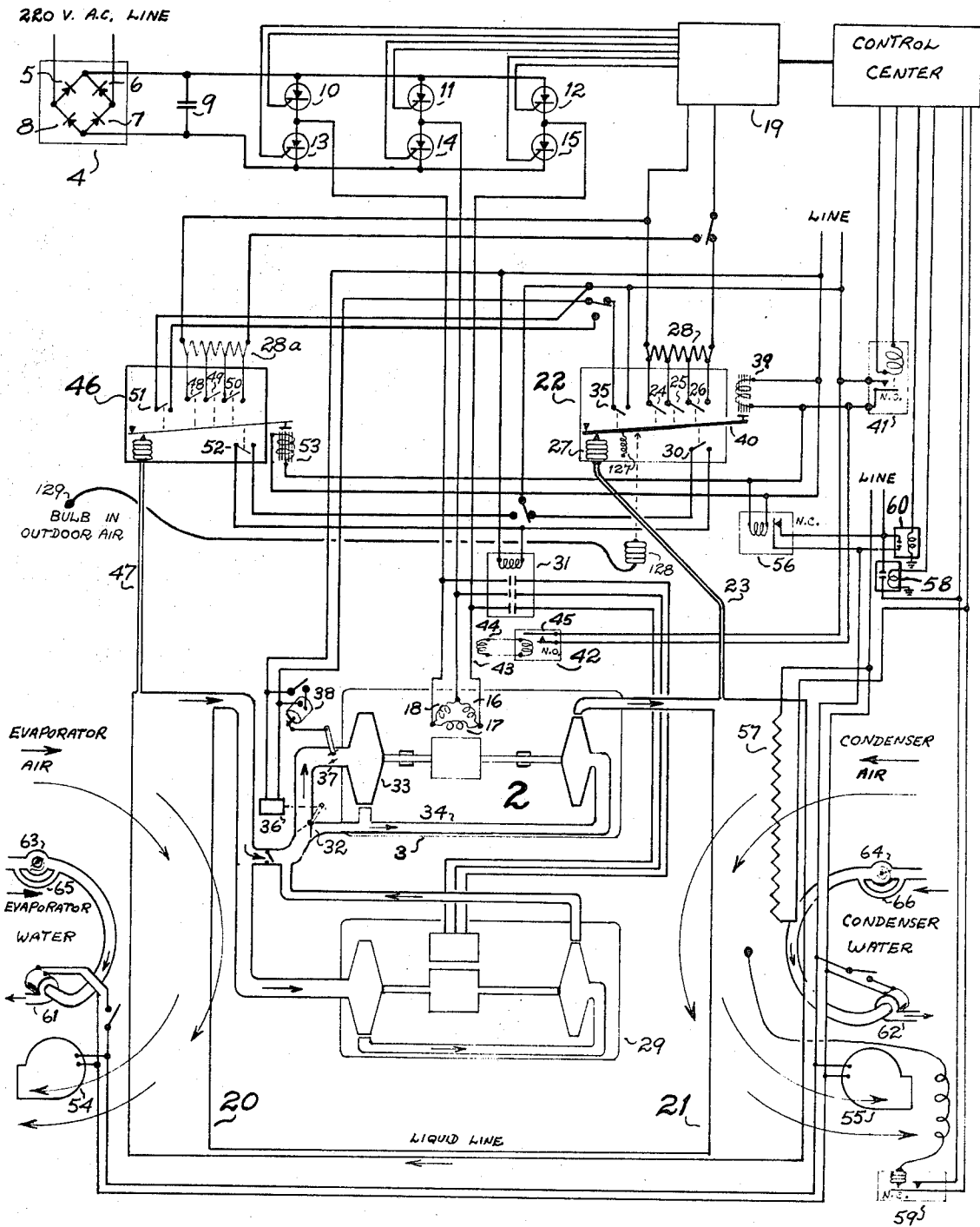
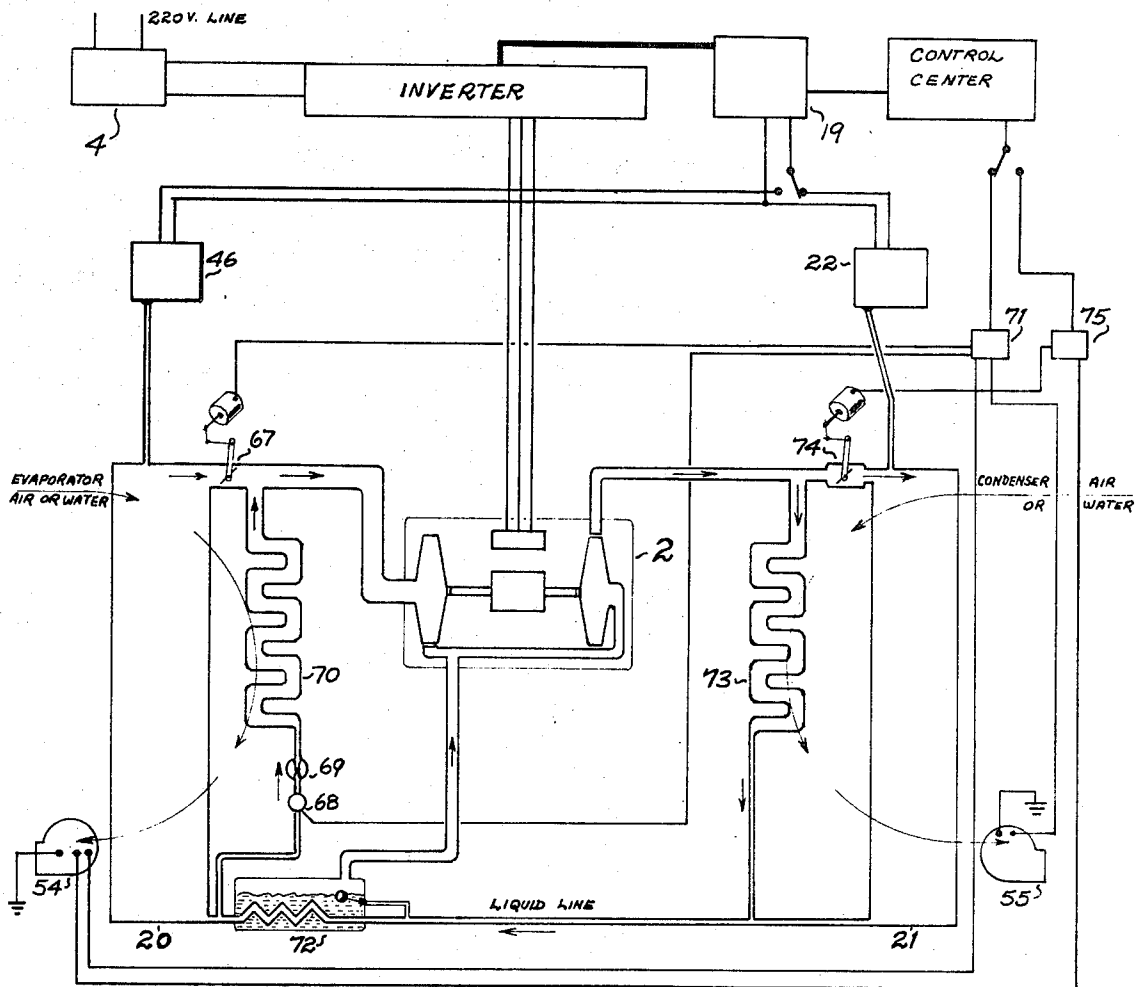
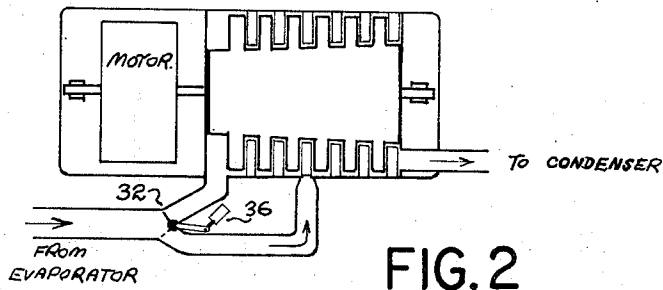


FIG. 1

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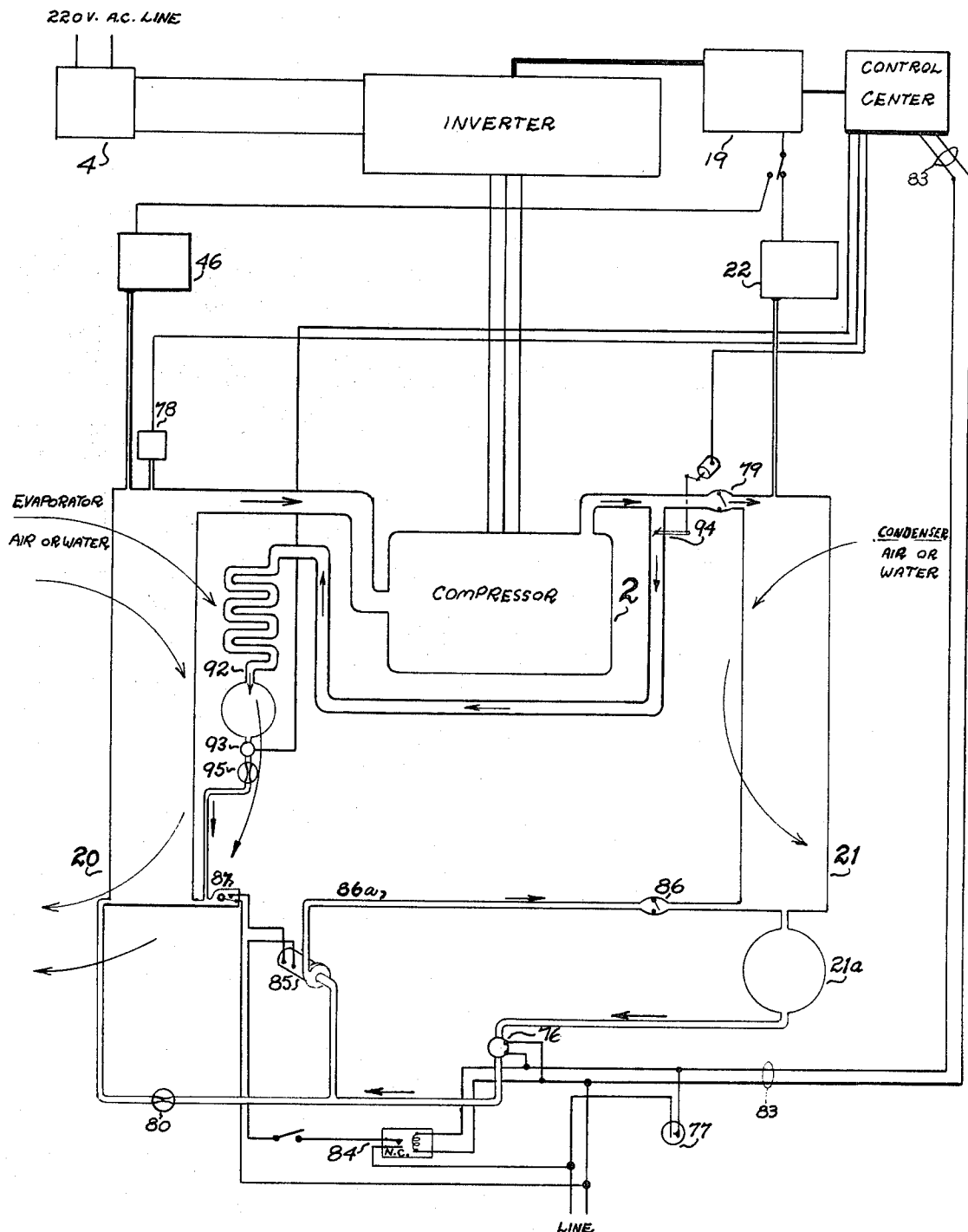


FIG. 4

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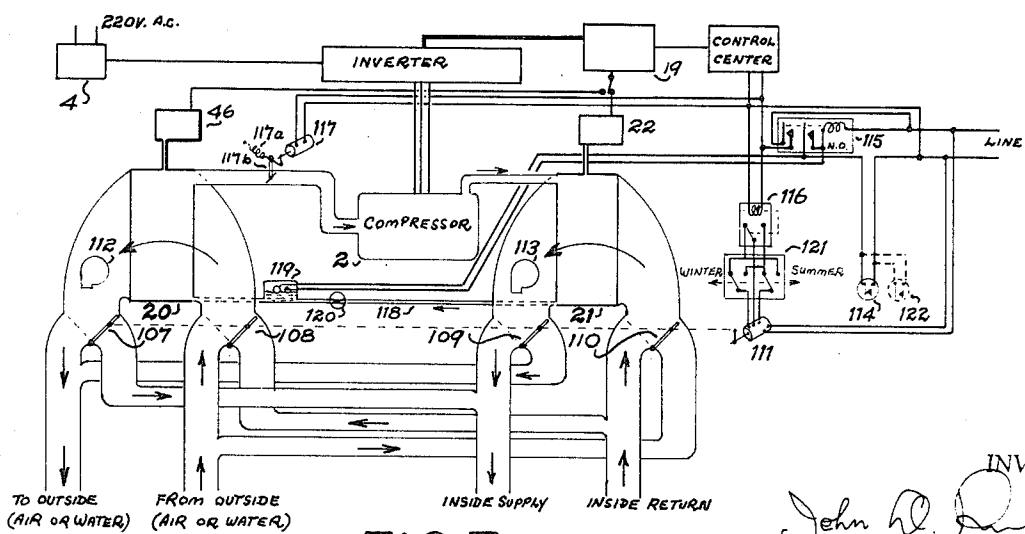
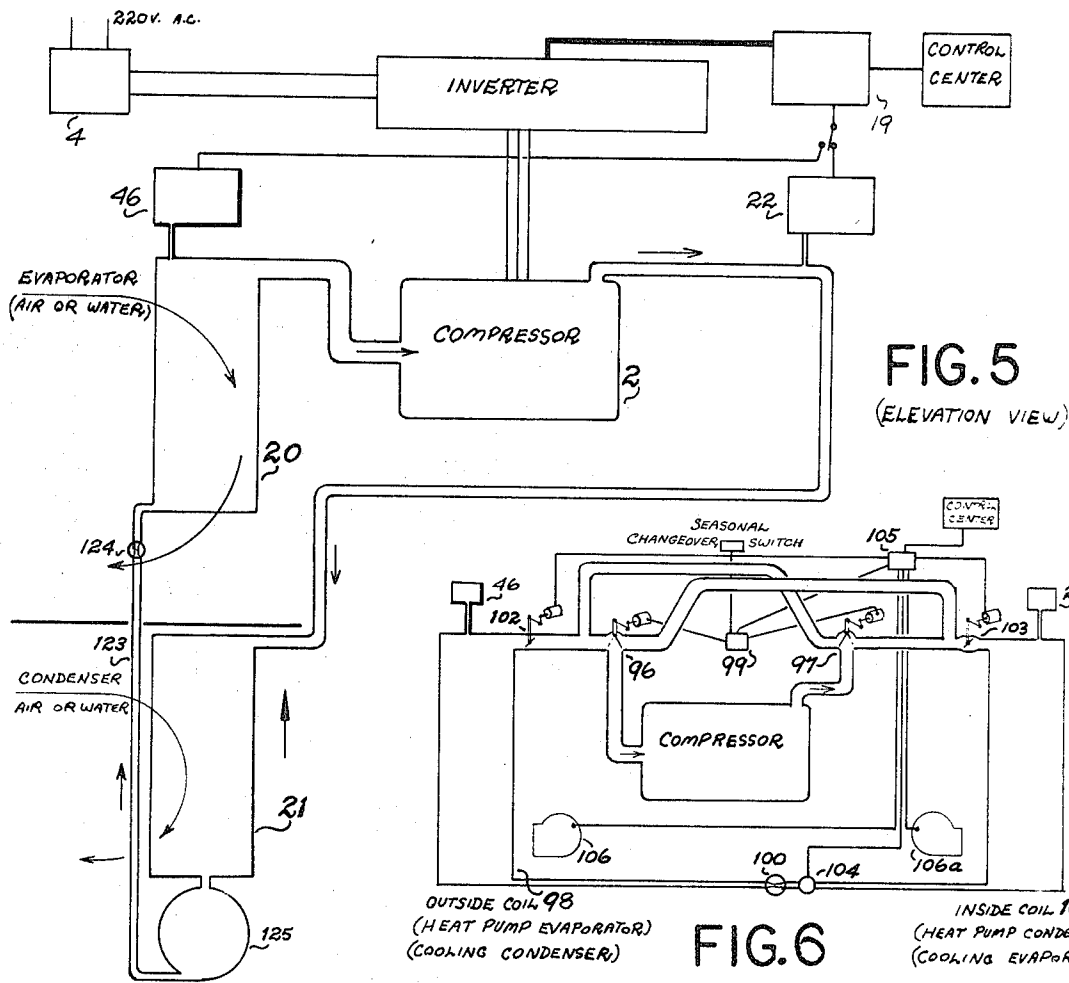


FIG. 7

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CENTRIFUGAL HEAT PUMP WITH OVERLOAD PROTECTION

This invention is a continuation in part of our earlier invention entitled "SMALL CENTRIFUGAL HEAT PUMP," Ser. No. 37,779 filed on May 15, 1970.

This invention is also similar in many respects to our earlier inventions, U.S. Pat. Nos. 3,449,922, 3,447,335, and 3,499,297. Similarly to these inventions the object is to produce an electrically powered mechanical refrigeration system using hermetic, kinetic displacement compressors (centrifugal or axial flow) and which has very efficient capacity variation capabilities. As with our other inventions this capacity variation is achieved by variable speed driving of the compressor system. This is done by variable frequency conversion of the electric power supplied from an external source such as electrical power mains or any other source of electrical power. The compressor motors used by this invention are of the squirrel-cage induction type and their speed is dependent on the alternating frequency of the electric current supplied to them. This type also has no brushes and can be used in hermetic type systems. Hermetic systems of course do not use compressor shaft seals and with small high speed compressors this is very desirable.

This invention is mainly concerned with the variable speed drive to the compressor system and the control means associated therewith. Such variable speed drives can be applied to all sizes of kinetic displacement compressors, and in all kinds of application (heat pump, air conditioning, refrigeration).

However this invention relates primarily to the methods of varying compressor capacity which depend for their control on the system discharge pressure, with the system being used as a heat pump, or on the system suction pressure when the system is being used for cooling purposes.

Methods are also included which prevent compressor overloading at start up. This is done by building up the system discharge pressure prior to applying normal compressor speed control, by bypassing various stages of the compression system during start up, or by removing the liquid refrigerant from the evaporator when stopping the system, (so that on restarting there will not be a quantity of liquid refrigerant in the evaporator which would cause overloading).

This invention comprises:

A variable capacity, variable frequency, hermetic, mechanical refrigeration system using kinetic displacement (centrifugal or axial flow) compressor machinery and driven by a squirrel cage motor (or motors), and a variable frequency inverter to supply current to the motor (or motors).

A capacity controller, to control the inverter frequency, which is sensitive (and responsive) to the system discharge pressure with the system being used as a heat pump.

An additional compressor unit, used as a booster at low evaporator temperatures and controlled by the capacity controller.

A power operated bypass valve which bypasses a stage, or some stages of compression in the primary compressor (to reduce pumping head) and which is controlled by the capacity controller.

A timer which causes the capacity controller to be placed in its minimum capacity setting for a preset time during start up, to prevent system overloading.

A current sensing device which is an alternate means of terminating the limitation on the capacity controller at start up, and which can re-engage the limitation when compressor motor current becomes too high.

An alternate capacity controller which is sensitive (and responsive) to the system suction pressure with the system being used for cooling purposes.

A system of control of the flow of air (or water) through the evaporator or condenser (or both) by stopping the fans (or pumps), or by varying their speeds so that suitable operating temperatures in these components can be maintained, this being an alternate method of reducing system overloading.

A heater which heats the condenser prior to start up and by this alternate method compressor overloading due to low condensing pressure is avoided.

A secondary evaporator which is either in the form of a flash type liquid intercooler or a specialized small evaporator which can provide a source of vapor (at start up, and with the primary evaporator choked off) so that by this alternate method, temperature can be built up in the condenser before the primary evaporator is employed.

A secondary condenser of relatively smaller capacity which can be employed (at start up and with the primary compressor choked off) so that the temperature of the evaporator can be reduced before the primary condenser is employed, as an alternate method of preventing overloading at start-up.

A pump down system utilizing a liquid line solenoid valve, a checkvalve and a low pressure switch which enables the system evaporator to be cleared of liquid refrigerant when it is stopped, (to prevent start-up overloading).

An alternate pump down system utilizing a liquid line solenoid valve, checkvalves, and a small liquid pump which pumps the liquid refrigerant out of the evaporator into the condenser when the compressor is stopped.

An alternate pump down system utilizing a pump down condenser-receiver which is located in the cool environment of the evaporator and having valves to shut it off from contact with normal vapor flow, and into which the refrigerant charge can be pumped (in vapor form) by the compressor, and where it is condensed, and stored while the compressor is stopped.

An alternate system of clearing the operating evaporator of liquid refrigerant when the invention is used as a convertible heat pump/cooling system (with refrigerant changeover valves) by reversing the changeover valves, when the system is to be stopped, and running the compressor until the liquid is forced from the operating evaporator into the operating condenser. Of course the functions of condenser and evaporator are reversed while this is being done. Valves then hold the liquid trapped in the condenser.

An alternate system of clearing the evaporator of liquid refrigerant when the invention is used as a convertible heat pump/cooling system, with changeover dampers, (or water valves) which can be reversed, while the compressor is stopped, so that the liquid refrigerant is forced (by the resulting pressure buildup) from the evaporator into the condenser.

A drain back system, which arrangement causes the liquid refrigerant to drain from the evaporator into the condenser (or a receiver) when the compressor is stopped and which is an alternate method of clearing liquid refrigerant from the evaporator.

In the drawings:

FIG. 1 shows systems of controlling compressor pumping head and of controlling evaporator and condenser temperatures.

FIG. 2 shows an axial flow compressor (with bypass of some stages).

FIG. 3 shows secondary evaporator and condenser coils.

FIG. 4 shows some pump-down systems.

FIG. 5 shows an arrangement for drain-back of refrigerant from the evaporator to the condenser.

FIG. 6 shows a convertible heat pump/cooling system with changeover refrigerant valves and a pump down system.

FIG. 7 shows a convertible heat pump/cooling system with changeover dampers (or water valves) and a pump-down system.

COMPRESSOR (FIG. 1)

FIG. 1 shows primary compressor 2 which is a two stage centrifugal compressor, with hermetic enclosure 3.

FREQUENCY CONVERTER (FIG. 1)

FIG. 1 illustrates, in simple form, a high frequency converter of typical specifications for supplying power to the compressor motor. The 220 v. A.C., 60 Hertz (cycles per

second), single phase supply is first rectified by the bridge rectifier 4 using solid state diodes 5,6,7,8. This pulsating D.C. output is smoothed by filter capacitor 9 and fed to the silicon controlled rectifiers 10,11,12,13,14,15 which switch into the three phase motor windings 16,17,18 of the motor. The firing of the silicon controlled rectifiers 10,11,12,13,14,15 is controlled by the variable frequency phase sequencer (or trigger circuit) 19. This circuit triggers and turns off the silicon controlled rectifiers in the necessary sequence for a three phase operation. The frequency of the resulting three phase supply is variable by changing the frequency of the sequencer oscillations.

By this method the speed of rotation of the compressor motor is controlled since this motor is of the squirrel-cage induction type and its speed is dependent on its supply frequency. Since the capacity of a centrifugal compressor varies basically as the cube of the rotation speed, then the operating capacity of the compressor unit will be approximately reduced to 40 percent of full capacity by a 25 percent drop in the rotation speed. This would be a typical range of capacity variation, with a span of about 40° F. in evaporator temperature (0° to 40° F.). "Capacity" in this case refers to the work done by the compressor as expressed in horsepower. Actually this capacity is dependent vary largely, on the pressure against which the compressor is working (or the compression ratio between the condenser and evaporator pressures).

There are several methods of achieving the frequency conversion to control motor speed but an electronic converter as described above is preferred since the necessary frequency changes can be accomplished simply by changing the frequency in the trigger circuit 19.

HEAT PUMP OPERATION (FIG. 1)

FIG. 1 shows compressor 2 drawing vapor from evaporator 20 which is in contact with the outside air and thus provides a source of heat. Condenser coil 21 is contacting the air inside the heated space and is thus heating it. In this invention the pumping head of the compressor system is the pressure difference between the evaporator pressure and the condensing pressure, the compressor system being applied to provide this pressure difference. Controller 22 is a pressure sensitive device which is the means of controlling the frequency of sequencer 19 and is sensitive to the condensing pressure in condenser 21 to which it is connected by line 23. That is, when the outside air temperature is lowered the suction pressure in evaporator 20 is also lowered, and since the pumping head of compressor 2 is relatively constant at any given rotation speed, then the condensing pressure will also be lowered. Controller 22 senses this drop in pressure and causes the frequency of sequencer 19 to be increased. This speeds up the compressor and increases its pumping head and the condensing pressure is thus kept at the desired level. It is necessary that the condensing pressure be kept at a reasonable level so that the condensing temperature also can be kept high and thus the heating function of the heat pump maintained. Similarly an undesirable raising of condensing pressure (due to warmer outside conditions) is compensated by a slowing down of the compressor. Controller 22 is shown with switches 24,25,26, which are actuated, a step at a time, by movement of bellows 27 as it responds to varying condensing pressures. Switches 24,25,26 short out portions of resistor 28, the resistance of which is the basis of control of sequencer 19. This arrangement of controller 22 gives four steps of capacity which are engaged automatically in response to pressure variations.

Alternative arrangements are the use of water flowing over evaporator 20 (as a source of heat) and the use of water flowing over condenser 21 (with a hydronic circulation system). Controller 22 operates in the same manner with these arrangements.

When very cold evaporator air (or water) causes a need for additional pumping head from the compressor system, booster compressor 29 is started up. When switch 30 in controller 22

is actuated (by a fall in pressure in the condenser) contactor 31 switches current to compressor 29. When conditions improve and pressure in the condenser rises, switch 30 opens and the booster is shut off.

When warm evaporator air (or water) causes a need for minimum pumping head from compressor 2, bypass valve 32 is actuated which shuts off the flow of vapor to compressor stage 33 and opens up a flow directly into transfer pipe 34. When switch 35 in controller 22 is actuated (by a rise in pressure in the condenser), solenoid 36 operates bypass valve 32. Such a bypass arrangement can be made past any stage or a group of stages in a multi-stage system. Also more than one bypass valve can be used and the pumping head varied over a wide range by progressive engagement of bypass valves. FIG. 2 shows how bypass valve 32 can be used similarly to bypass a number of stages of an axial flow compressor.

Alternately a reduction in pumping head can be achieved by the use of Pre-Rotation Vanes which are conventionally used for reduction of pumping head on centrifugal compressors. Vanes 37 are shown (in FIG. 1) operated by motor 38. These Vanes are sometimes referred to as "Variable Inlet Guide Vanes" and comprise of a number of movable vanes placed in the inlet passage of a centrifugal stage and which control the direction of flow of vapor entering the impeller. When set to reduce the pumping head they cause a swirling movement of the vapor in a direction opposite to impeller rotation.

OVERLOAD PREVENTION (FIG. 1)

When the centrifugal (or axial flow) compressor is starting up after being stopped for any length of time there is a tendency to overload because the pressures in evaporator 20 and condenser 21 are nearly equal and there is a high rate of flow through the compressor. However, (with an air to air system) the evaporator soon cools down and the condenser heats up and normal operation is allowed. Our invention uses a method of providing a minimum pumping head at start up. Solenoid 39 on controller 22 pulls the actuating arm 40 so that switches 24,25,26 and 35 are in the minimum capacity settings, and switch 30 has booster 29 turned off. Solenoid 39 can be controlled by timer 41 to be engaged for a set time at start up or alternately it can be controlled by current sensing device 42. Solenoid 39 can be positively engaged at start up and disengaged by sensing device 42 when the current in motor lead 43 drops to a predetermined level, or device 42 can also be the means of engaging solenoid 39. That is, when the level of current in lead 43 increases to a predetermined point the current induced in pickup coil 44 causes switch 45 to be made and solenoid 39 energized. It can be seen that if the motor current level does not become high, as is the case when the evaporator is very cold (on start up) and the condenser warmer, then solenoid 39 will not be engaged at all.

COOLING OPERATION (FIG. 1)

When the system is used in cooling operation controller 46 is used which is sensitive to the system evaporator pressure to which it is connected by line 47. Means are shown for switching this alternate controller into the electrical circuits. Controller 46 is reverse acting, as compared to controller 22. That is, switches 48,49,50,51 make on fall of pressure and not on rise. And switch 52 makes on rise not on fall. By these switches, increased pumping head is provided as the evaporator pressure rises. Solenoid 53 pulls the actuating arm in the opposite direction to solenoid 39 when limiting pumping head at start up, but is also controlled by timer 41 or sensing device 42. The inside air (or water) is in contact with the evaporator in cooling operation and the outside air (or water) is in contact with the condenser. In other respects the operation is similar to heat pump operation.

COIL TEMPERATURE CONTROL (FIG. 1)

So far we have shown how the temperature in the condenser and the evaporator can be brought to suitable operating levels

(with-out compressor overloading) by running at reduced pumping head, however the time taken to reach this temperature can be reduced if fans 54,55 are stopped during the start-up period. The normally closed points on relay 56 control these fans. Another method of increasing the temperature in condenser coil 21 is by heater 57. This heater is activated as the first step in starting up the compressor system. Relay 58 responds to a signal from the Control Center and heater 57 starts to heat condenser 21. When a suitable temperature has been reached, temperature sensitive device 59 breaks and heater 57 is switched off and (through the Control Center) the compressor started. In this way an overloading of the compressor due to a heavy flow of vapor into a cold condenser is prevented. Fans 54,55 should be kept off for some time after the compressor is started up and timer 60 controls this time. Timer 60 is an alternate means of controlling the fans, to relay 56. The temperature to which coil 21 is pre-heated is higher than normal operating temperature to ensure sufficient temperature differential between it and the evaporator, since the evaporator will be at a higher temperature than normal while the compressor is stopped. The use of heater 57 is a method of overload prevention that is alternative to the use of solenoid 39.

When water is the medium circulated over the condenser and the evaporator (as when hydronic circulation is used) pumps 61,62 replace fans 54,55. In this application, when the compressor cycles off and on to maintain correct temperature there is no problem with overloading since the temperature of the water over the condenser and evaporator is substantially at operating temperature levels and the temperature differential is adequate. But if the compressor is stopped (for any reason) long enough for the evaporator water and condenser water to equalize in temperature then precaution must be taken to prevent overload on start up. Pumps 61,62 can be shut down in the same manner as when condenser 21 is air contacted. However when pumps 61,62 are restarted there should be some control to restrict the circulation through evaporator 20 and condenser 21, otherwise the cold water in evaporator 20 and the hot water in condenser 21 would be removed and replaced by average temperature water and overloading would occur. Thermostat valves 63,64 are placed in the flow of water to the evaporator and condenser coils. Thermostat 63 opens on fall of temperature and thermostat 64 opens on rise of temperature. By-passes 65,66 allow a minimal flow when the thermostats are closed.

These methods of coil temperature control apply in both heat-pump and cooling operation.

SECONDARY COILS (FIG. 3)

An alternate method of building up heat in the condenser is by the use of a secondary evaporator when starting the system; (to prevent overloading). At start up, throttle valve 67 (FIG. 3) shuts off primary evaporator 20 from the compressor and solenoid valve 68 opens to allow liquid to flow through restrictor 69 into secondary evaporator coil 70. A moderate flow of vapor is thus provided through the compressor 2, and compressed into condenser 21, whose temperature is thus increased. Fan 55 remains shut off, but fan 54 runs while heat is built up and then valve 67 is opened and solenoid valve 68 closed. (An alternate arrangement with this method is to delete solenoid valve 68 and then secondary evaporator 70 remains permanently connected to the system). The system is then run for some time with fans 54,55 shut off, and evaporator 20 is cooled. Fans 54,55 are then started up and normal operation is established. Timer 71 is used to control the engagement of valves 67,68 and cycling of fans 54,55. A conventional flash type intercooler 72 can be used as a secondary evaporator (as an alternate to specialized evaporator 70) and provide a flow of vapor while valve 67 is closed, but still function as an intercooler when the system is in normal operation.

An alternate method of cooling down the evaporator coil 20 when starting the system (to prevent overloading) is by the use

of a secondary condenser 73. At start up, throttle valve 74 shuts off primary condenser 21 from the compressor. A moderate flow of vapor into this small sized condenser 73 is condensed to liquid and flows into the main liquid line. The evaporator 20 is thus cooled down slowly. Fan 54 remains shut off, but fan 55 runs while the evaporator is cooled. Then valve 74 is opened, fan 54 started and normal operation established. Secondary condenser 73 remains in operation as part of the total condenser capacity. Timer 75 is used to control valve 74 and to cycle fan 54. (Means are shown for switching this alternate timer into the control circuit.)

The invention arrangement as shown in FIG. 3 is controlled (for capacity) in heating and cooling operation by controllers 22,46 in the manner already described.

EVAPORATOR PUMP DOWN (FIG. 4)

An alternate method of preventing overloading at start up is to remove the bulk of liquid refrigerant from the evaporator when stopping the compressor (by a pump-down cycle) so that when restarting, the liquid is introduced into the evaporator after the compressor has started and at a rate which prevents there being an excess of vapor available for compression. When the system is to be stopped solenoid valve 76 (FIG. 4) is closed by room thermostat 77 and no more liquid flows into evaporator 20. The compressor continues to run until the liquid in the evaporator is removed. At this time the pressure is quite low and pressure switch 78 opens and causes the compressor to stop. Checkvalve 79 closes and the bulk of refrigerant in the system is held in the condenser 21, or in its extension receiver 212. If pressure builds up again in the evaporator due to leakage past solenoid valve 76 or checkvalve 79 the compressor starts up briefly and pumps it out. To re-start the system, solenoid valve 76 is opened and the liquid flows back into evaporator 20 through restrictor 80 which is of a suitable size so that the rate of flow of liquid through it at any time is no more than the rate of flow through the system at maximum capacity. When pressure builds up in the evaporator, switch 78 starts up the compressor. Restrictor 80 prevents overloading of the compressor by preventing too rapid entry of refrigerant into the evaporator.

Another method of removing the liquid refrigerant from the evaporator is shown in FIG. 4. When the system is to be stopped, thermostat 77 opens, causing solenoid valve 76 to close. Also control circuit 83 signals the control center to stop the compressor. The points in relay 84 close causing a small centrifugal type liquid pump 85 to start pumping the liquid from evaporator 20 through checkvalve 86 and into condenser 21. Means are shown for switching this alternate device into the control circuit. Checkvalve 79 can be used to prevent migration of vapor back through the compressor. Floatswitch 87 keeps pump 85 running until the liquid in the evaporator is removed, at which time the float drops and the pump shuts off. On restarting, room thermostat 77 signals the control center (through circuit 83) to start the compressor. Solenoid valve 76 is opened, and the liquid refrigerant is introduced slowly back into the evaporator 20 through restrictor 80. Pump 85 is kept out of operation since the coil of relay 84 is energized.

Another alternate pump down method is shown in FIG. 4 with condenser/receiver 92 placed in the cool environment of evaporator 20. When the system is to be stopped solenoid valve 93 is closed and valve 94 is opened. Compressor 2 continues to run and since condenser/receiver 92 is colder than condenser 21, condensation will occur in it until all the liquid in the system is held in it. Low pressure switch 78 is actuated (when there is no liquid remaining in evaporator 20) and causes the compressor to stop and valve 94 to close. On restarting, valve 93 is opened and liquid flows slowly back into the evaporator through restrictor 95. When pressure returns to pressure switch 78 the compressor is started, but valve 94 is kept closed during normal running.

With the pump-down methods shown in FIG. 4 controllers 22,46 are used to control system capacity as shown previously.

PUMP DOWN BY SYSTEM REVERSAL (FIG. 6)

FIG. 6 shows a convertible heat pump/cooling system, with conventional changeover valves 96,97. Outside coil 98 is the system evaporator in heat pump operation (as shown in FIG. 6). When the system is to be stopped, valves 96,97 are reversed to the cooling position through changeover relay 99, which forces the liquid refrigerant from the outside coil 98 through restrictor 100 and into inside coil 101. Valves 102,103,104 are then closed, the compressor stopped, and the liquid is held in the inside coil. The length of time the system is run in cooling setting before stopping the compressor and shutting valves 102,103, 104 can be controlled by timer 105. Circulating means (fans or pumps) 106, 106a are stopped during this reversal time. To start the system back up (into heat pump operation) valves 96,97 are set back to the heat pump position, valves 102,103,104 opened and the compressor started. The liquid refrigerant slowly flows back to the outside coil 98 through restrictor 100 and normal heat pump function is resumed.

When the system is functioning in cooling operation and is about to be stopped a similar routine is followed. That is, changeover valves 96,97 reverse for a preset time (to heating position). The liquid is transferred from the inside coil 101 (cooling evaporator) to the outside coil 98 (cooling condenser) and valves 102,103,104 close and the compressor stops. Starting is as already described.

System capacity control (in heating and cooling) is by means of controllers 22,46 as already described. A seasonal changeover switch controls changeover relay 99 and selects summer or winter operation.

SYSTEM REVERSAL (DAMPERS)

FIG. 7 shows a convertible heat pump/cooling system with conventional changeover dampers (or water valves 107,108, 109, 110 operated by changeover motor 111, and shown set in the heating position, with the evaporator circulator means 112 (fan or pump) drawing outside air (or water) over the evaporator 20, and with the condenser circulator means 113 (fan or pump) drawing inside air (or water) over the condenser 21. When thermostat 114 opens, the compressor 2 is stopped (through the control center circuits) and through hold-out relay 115, which is de-energized. Reversing relay 116 is de-energized, which causes motor 111 to reverse the setting of dampers (or water valves) 107,108,109,110. And motor 117 is de-energized, which allows spring 117a to pull valve 117b closed, which shuts off evaporator 20 from the compressor. The circulator means 112,113 continue to run. While operating (in heating function) the cold evaporator was in contact with the cold outside air (or water). However when stopped the warmer inside air (or water) is being passed over the evaporator 20 and the cold outside air (or water) over the condenser. This causes greater pressure in the evaporator than in the condenser and the liquid refrigerant then flows through the liquid line 118 into the condenser 21 where it remains. When the liquid is removed from evaporator 20, floatswitch 119 makes which will allow hold-out relay 115 to be reset when the system is to be restarted. This precaution prevents the system from being restarted before all of the liquid is removed from the evaporator. To restart the system thermostat 114 remakes, which activates relay 115 (if floatswitch 119 is made), the compressor is started, valve 117b opened, and reversing relay 116 causes the dampers (or valves) to move back to their normal heating position. Pressure is built up in condenser 21 and the liquid forced slowly back (through restrictor 120) into evaporator 20. This arrangement allows the system to be restarted without overloading. The operation described is used when the system is functioning as a heat pump under the control of controller 22 (already described and shown in FIG. 1). However when the system is functioning as a cooling system (in summer) controller 46 controls capacity and the normal running position of dampers 107, 108,109,110 is the reverse of that shown (for heating operation). Seasonal changeover switch 121 selects summer (or

winter) operation. Reversing relay 116 is still used to reverse the dampers, back (to the heating position) while the system is stopped. Valve 117 and floatswitch 119 still function in the same way. Thermostat 114 is replaced by thermostat 122 which makes on rise of temperature.

LIQUID DRAIN BACK (FIG. 5)

FIG. 5 shows the invention with the evaporator 20 mounted at a level higher than the condenser 21. In operation the greater pressure at condenser 21 forces liquid up liquid line 123, through restrictor 124 and into evaporator 20 where a quantity of liquid is present. However when the compressor stops, the pressures equalize and the liquid drains down to the condenser 21 (or receiver 125). Then on restarting, the liquid is transferred to evaporator 20 slowly through restrictor 124 and overloading is prevented.

This prevents refrigerant migration from the receiver to the cooler evaporator. Capacity control in heating and cooling operation is by controllers 22, 46 as already described.

EXPANSION VALVES

In the preceding specifications the evaporator 20 has not been specified as a dry expansion type or a flooded type and no mention has been made of expansion valves or capillary tube restrictors as used in dry expansion evaporators; or evaporator liquid level control valves and restrictors which can be used on flooded evaporators. Either type of evaporator however can be used with this invention and no single type of expansion valve is specified.

OUTSIDE TEMPERATURE SENSOR (HEAT PUMP)

With the functioning of controller 22 (shown in FIG.1) as already described, the system discharge pressure (and thence the heat pump condenser temperature) is kept at a substantially constant level. There is, of course, a range of operation over which the switches 35,24,25,26,30 are operated as the pressure from bellows 27 balances out the pressure of control spring 127. A typical set of operating pressures at which switches 35,24,25,26 will make (with F-12 refrigerant) are : psig, 180,181,182,183. Each of the switches must also have a sizable on-off operating pressure differential (which is greater than the pumping head change effected by its activation) so that when a switch is activated by a change in operating environment (which causes a change in condenser pressure) the resulting increase or decrease of compressor pumping head will not cause the switch to be de-activated immediately. The matching break pressures for the above make pressures might be respectively : psig, 170,171,172,173. The larger the number of switches on resistor 28 the smaller the switch differential needs to be and the more precise the control by controller 22.

However with varying outside temperatures it is desirable to operate the heat producing condenser 21 at various temperatures. That is, when the outside temperature is quite low (e.g. 10°) the typical range of pressures given (psig 170-183) which correspond to condenser temperatures about 130° are appropriate. But with milder outside temperatures (e.g. 50°) a lower range of pressures (psig 107-120) which co-respond to condenser temperatures about 100° are more appropriate. Bellows 128 moves in response to the outside temperature at bulb 129. At minimum outside temperature, bellows 128 contracts and has no effect on controller 22 allowing it to control the condenser at the higher pressures (psig 170-183). But at higher outside temperature (50°) bellows 128 expands and exerts pressure on arm 40 which tends to counteract the pressure of spring 127. This causes the controller 22 to operate the condenser at a lower pressure range (psig 107-120). Throughout a whole range of outside temperatures e.g., 10°-50° the condenser will operate at a range of appropriate pressures to produce condenser temperatures ranging from 130° to 100°.

We claim:

1. In combination a variable capacity heat pump used for heating an air filled space and comprising kinetic displacement vapor compression means direct driven by variable speed, alternating current, electric motor machinery of the squirrel-cage induction type and the said compression means and motor machinery being combined in a common hermetic enclosure, to pump refrigerant vapor from a refrigerant evaporating means to a condensing means, a variable frequency inverter means using sequential switching equipment to switch electrical current from an external source into the windings of the said motor machinery in such a manner to provide a variable frequency flux through the said windings, and thus achieve a variable speed rotation of the said motor machinery, since the rotation speed of this type of motor is dependent on the frequency of the current supplied to it, a pressure sensing means which is sensitive only to the refrigerant vapor pressure in the said condenser, and the frequency of the said variable frequency inverter is controlled by this said pressure sensing means so that when operating conditions cause the pressure in the said condenser to be undesirably low the compressor is speeded up till a suitable condenser pressure is reached and similarly when the condenser pressure is too high the compressor is slowed down, and a means of limiting the effective pumping head of the said vapor compression means for a period of time when starting the vapor compression means after its having been stopped so that overloading of the said vapor compression means can be avoided, and means of controlling the said period of time.

2. In combination a variable capacity cooling system used for cooling an air filled space and comprising kinetic displacement vapor compression means direct driven by variable speed, alternating current, electric motor machinery of the squirrel-cage type and the said compression means and motor machinery being combined in a common hermetic enclosure, to pump refrigerant vapor from a refrigerant evaporating means to a condensing means, a variable frequency inverter means using sequential switching equipment to switch electrical current from an external source into the windings of the said motor machinery in such a manner to provide a variable frequency flux through the said windings, and thus achieve a variable speed rotation of the said motor machinery, since the rotation speed of this type of motor is dependent on the frequency of the current supplied to it, a pressure sensing means which is sensitive only to the refrigerant vapor pressure in the said evaporator, and the frequency of the said variable frequency inverter is controlled by this said pressure sensing means so that when operating conditions cause the pressure in the said evaporator to be undesirably high the compressor is speeded up till a suitable evaporator pressure is reached and similarly when the evaporator pressure is too low the compressor is slowed down, and a means of limiting the effective pumping head of the said vapor compression means for a period of time when starting the vapor compression means after its having been stopped so that overloading of the said vapor compression means can be avoided, and means of controlling the said period of time.

3. In combination a variable capacity heat pump used for heating an air filled space and comprising kinetic displacement vapor compression means direct driven by variable speed, alternating current, electric motor machinery of the squirrel-cage induction type and the said compression means and motor machinery being combined in a common hermetic enclosure, to pump refrigerant vapor from a refrigerant evaporating means to a condensing means, a variable frequency inverter means using sequential switching equipment to switch electrical current from an external source into the windings of the said motor machinery in such a manner to provide a variable frequency flux through the said windings, and thus achieve a variable speed rotation of the said motor machinery, since the rotation speed of this type of motor is dependent on the frequency of the current supplied to it, a pressure sensing means which is sensitive only to the refrigerant vapor pressure in the said condenser, and the frequency of the

said variable frequency inverter is controlled by this said pressure sensing means so that when operating conditions cause the pressure in the said condenser to be undesirably low the compressor is speeded up till a suitable condenser pressure is reached and similarly when the condenser pressure is too high the compressor is slowed down, and a means of controlling the temperature of said evaporating means and the said condensing means towards establishing suitable operating temperatures in these evaporating and condensing means, when starting the said heat pump after its having been stopped, to avoid overloading of the said compression means.

4. In combination a variable capacity cooling system used for cooling an air filled space and comprising kinetic displacement vapor compression means direct driven by variable speed, alternating current, electric motor machinery of the squirrel-cage induction type and the said compression means and motor machinery being combined in a common hermetic enclosure, to pump refrigerant vapor from a refrigerant evaporating means to a condensing means, a variable frequency inverter means using sequential switching equipment to switch electrical current from an external source into the windings of the said motor machinery in such a manner to provide a variable frequency flux through the said windings, and thus achieve a variable speed rotation of the said motor machinery, since the rotation speed of this type of motor is dependent on the frequency of the current supplied to it, a pressure sensing means which is sensitive only to the refrigerant vapor pressure in the said evaporator, and the frequency of the said variable frequency inverter is controlled by this said pressure sensing means so that when operating conditions cause the pressure in the said evaporator to be undesirably high the compressor is speeded up till a suitable evaporator pressure is reached and similarly when the evaporator pressure is too low the compressor is slowed down, and a means of controlling the temperature of the said evaporating means and the said condensing means towards establishing suitable operating temperatures in these evaporating and condensing means, when starting the said cooling system after its having been stopped, to avoid overloading of the said compression means.

5. In combination a variable capacity heat pump used for heating an air filled space and comprising kinetic displacement vapor compression means direct driven by variable speed, alternating current, electric motor machinery of the squirrel-cage induction type and the said compression means and motor machinery being combined in a common hermetic enclosure, to pump refrigerant vapor from a refrigerant evaporating means to a condensing means, a variable frequency inverter means using sequential switching equipment to switch electrical current from an external source into the windings of the said motor machinery in such a manner to provide a variable frequency flux through the said windings, and thus achieve a variable speed rotation of the said motor machinery, since the rotation speed of this type of motor is dependent on the frequency of the current supplied to it, a pressure sensing means which is sensitive only to the refrigerant vapor pressure in the said condenser, and the frequency of the said variable frequency inverter is controlled by this said pressure sensing means so that when operating conditions cause the pressure in the said condenser to be undesirably low the compressor is speeded up till a suitable condenser pressure is reached and similarly when the condenser pressure is too high the compressor is slowed down, and a means of removing any refrigerant in liquid form from the said evaporating means after the said compression means has been called to stop, and means of gradually re-introducing the said refrigerant in liquid form into the said evaporating means after the said compression means has re-started, to avoid overloading of the said compression means.

6. In combination a variable capacity cooling system used for cooling an air filled space and comprising kinetic displacement vapor compression means direct driven by variable speed, alternating current, electric motor machinery of the

squirrel-cage induction type and the said compression means and motor machinery being combined in a common hermetic enclosure, to pump refrigerant vapor from a refrigerant evaporating means to a condensing means, a variable frequency inverter means using sequential switching equipment to switch electrical current from an external source into the windings of the said motor machinery in such a manner to provide a variable frequency flux through the said windings, and thus achieve a variable speed rotation of the said motor machinery, since the rotation speed of this type of motor is dependent on the frequency of the current supplied to it, a pressure sensing means which is sensitive only to the refrigerant vapor pressure in the said evaporator, and the frequency of the said variable frequency inverter is controlled by this said pressure sensing means so that when operating conditions cause the pressure in the said evaporator to be undesirably high the compressor is speeded up till a suitable evaporator pressure is reached and similarly when the evaporator pressure is too low the compressor is slowed down and a means of removing any refrigerant in liquid form from the said evaporating means after the said compression means has been called to stop, and means of gradually re-introducing the said refrigerant in liquid form into the said evaporating means after the said compression means has re-started, to avoid overloading of the said compression means.

7. In combination a variable capacity heat pump used for heating an air filled space and comprising kinetic displacement vapor compression means direct driven by variable

speed, alternating current, electric motor machinery of the squirrel-cage induction type and the said compression means and motor machinery being combined in a common hermetic enclosure, to pump refrigerant vapor from a refrigerant evaporating means to a condensing means, a variable frequency inverter means using sequential switching equipment to switch electrical current from an external source into the windings of the said motor machinery in such a manner to provide a variable frequency flux through the said windings, and thus achieve speed rotation of the said motor machinery, since the rotation speed of this type of motor is dependent on the frequency of the current supplied to it, a pressure sensing means which is sensitive to the refrigerant vapor pressure in the said condenser, and the frequency of the said variable frequency inverter is controlled by this said pressure sensing means so that when operating conditions cause the pressure in the said condenser to be low the compressor is speeded up till a suitable condenser pressure is reached and similarly when the condenser pressure is too high the compressor is slowed down and in this manner a predetermined condenser pressure level is maintained, and a means of determining the said predetermined condenser pressure which means is sensitive to the outdoor air temperature, so that higher condenser pressure levels are maintained at low outdoor air temperatures and lower condenser pressure levels are maintained at higher outdoor air temperatures.

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