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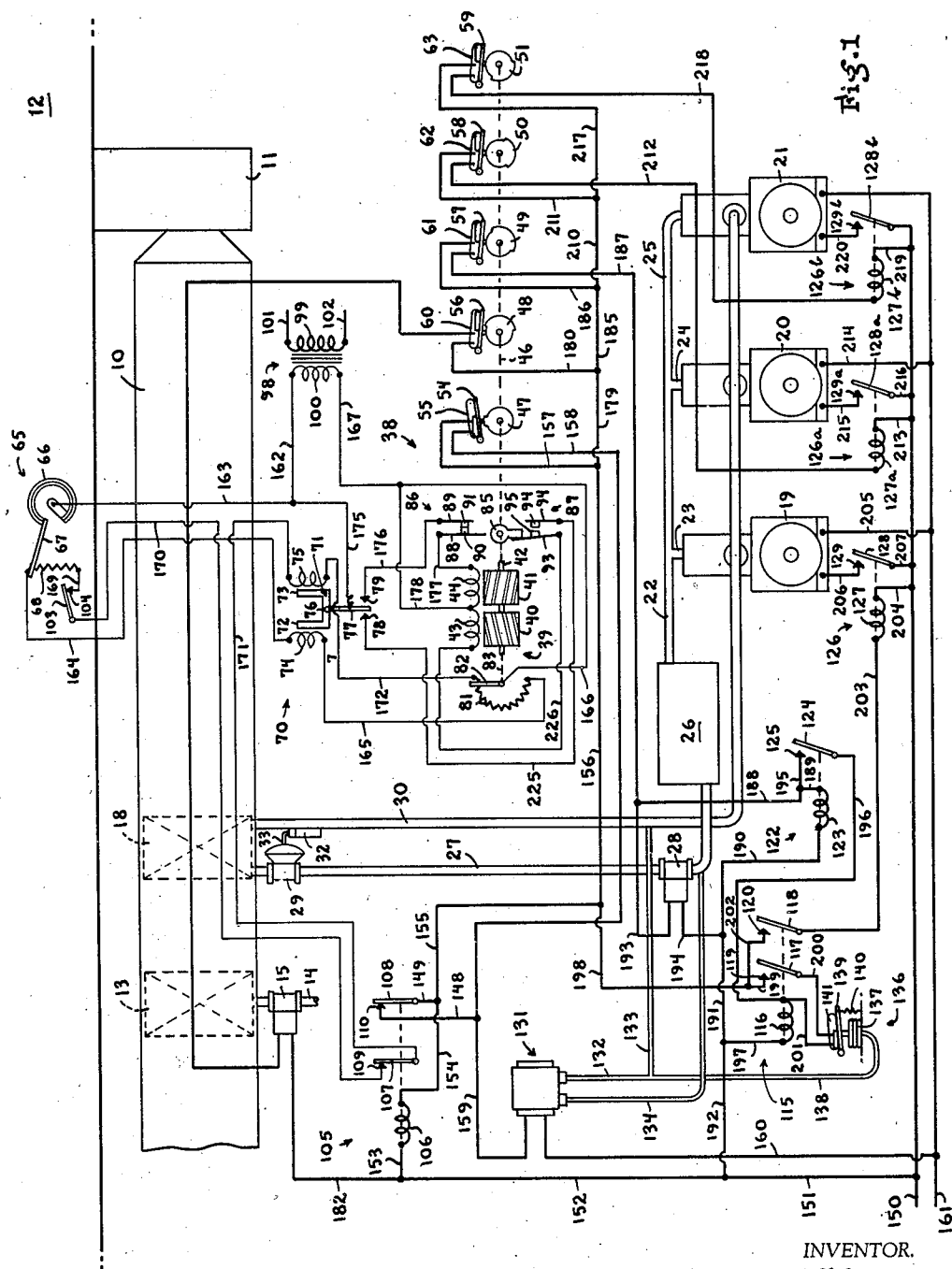
W. L. McGRATH

2,364,459

CONTROL OF REFRIGERATION APPARATUS

Filed Oct. 25, 1941

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

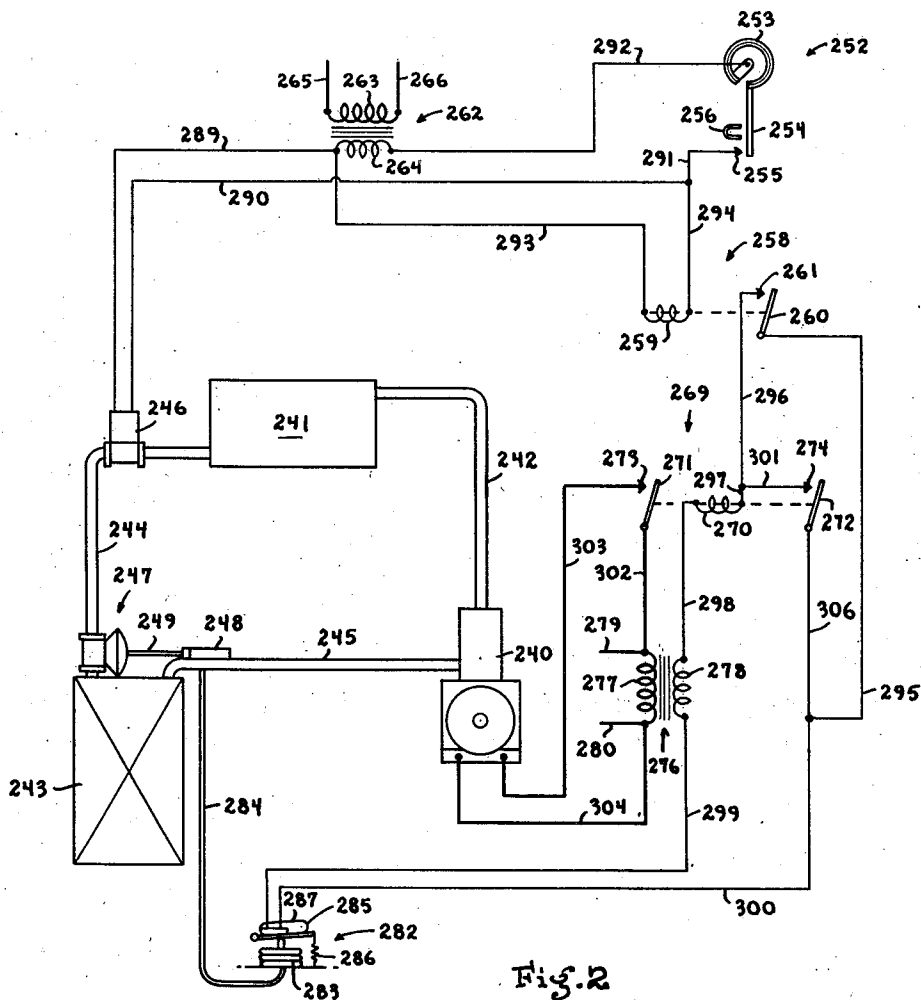


Fig. 2

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UNITED STATES PATENT OFFICE

2,364,459

CONTROL OF REFRIGERATION APPARATUS

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Application October 25, 1941, Serial No. 416,530

16 Claims. (Cl. 62—4)

The present invention relates to improvements in automatic controls particularly as adapted to refrigerating systems employing multiple compressors wherein the compressors are started and stopped in sequence.

The object of the invention is to provide improved means for causing one compressor to pump the refrigerant out of the evaporator upon a normal shut-down and to provide for power failure protection of all the compressors including the said one, that is, upon a power failure the control mechanism will return to an initial position from which it will recycle upon resumption of the power supply before any compressors are reenergized.

Another object is to provide manual shut-down means whereby upon a manual shut-down the control mechanism will automatically return to an initial position, but one compressor nevertheless pumping down the evaporator just as in the event of an automatic shut-down.

The details of my invention and numerous other of its objects and advantages will become apparent from the following description and drawings, wherein:

Fig. 1 represents a preferred form of my invention, and

Fig. 2 represents a modified and simpler form of the invention.

Referring to Fig. 1 of the drawings, number 10 designates a duct, the right end of which is connected to the suction side of a fan disposed within a housing 11. Air for conditioning a space 12 is circulated through duct 10 and discharged into the space by means of the fan. The air may be a mixture of outdoor air and recirculated air in accordance with common practice.

Disposed in the duct 10 is a heat exchanger or coil 13 through which cold water is passed for cooling the air, the cold water being admitted to the coil through a pipe 14. Interposed in the pipe 14 is an electric solenoid type control valve 15.

Also disposed in the duct 10 is an evaporator designated by the numeral 18 forming part of a direct expansion refrigeration system. The refrigeration system comprises three compressors 19, 20 and 21 which discharge into a common header 22 through pipes 23, 24 and 25 respectively. The header 22 is connected to a condenser 26. The condenser is connected to the evaporator 18 by a pipe 27, and interposed in the pipe 27 is an electric solenoid type stop valve 28 and also a thermostatic valve 29. The thermostatic valve 29 is of the usual type constructed

and arranged to maintain a constant degree of superheat at the outlet of the evaporator. The evaporator outlet is connected to a pipe 30 which is connected to the inlet of all the compressors 19, 20 and 21. The operating mechanism of the valve 29 includes an expansible chamber which is connected to a thermal bulb 32 by means of a capillary tube 33, the thermal bulb being disposed in intimate heat exchange relationship with the pipe 30 connected to the evaporator outlet. The thermal bulb 32 is filled with an expansible liquid which vaporizes, the gas expanding and contracting in accordance with the temperature in the outlet pipe 30.

The controls for the compressors constitute primarily a step controller designated by the numeral 38. The step controller 38 includes a reversible electric motor 39 having rotors 40 and 41 mounted on a shaft 42 and having windings 43 and 44 respectively associated with the rotors. The motor 39 drives a shaft 46, this shaft preferably being driven through a gear train at a slower speed than the speed of the shaft 42. Mounted upon the shaft 46 is a plurality of cams 47, 48, 49, 50, and 51. The cam 47 has a single dwell of relatively short angular extent, and this dwell is arranged to actuate a pivoted switch carrying lever 54, which carries a mercury switch 55. When the cam 47 is in the position shown on the drawings, the dwell engages the lever 54 tilting the mercury switch 55 to closed position as shown. Each of the cams 48 to 51 has a single dwell of substantially 180° angular extent, the dwells on the different cams being spaced relatively as shown on the drawings. Each of the cams 48 to 51 has a pivoted switch carrying lever associated therewith, these levers being designated by the numerals 56, 57, 58, and 59 respectively, the levers carrying mercury switches 60, 61, 62, and 63, respectively. When the shaft 46 is rotated in a counter-clockwise direction, the dwells on the cams will engage their respective levers and tilt their associated mercury switches into closed position, the switch 60 becoming closed first and the switches 61, 62 and 63 closing thereafter in sequence as the dwells of their respective cams are rotated into a position to engage the switch carrying levers. When the shaft 46 is rotated out of its initial position, the dwell of cam 47 disengages from lever 54 causing switch 55 to open so that switch 55 is normally closed only when the shaft 46 is in substantially initial position. After switches 60 to 63 have been closed, and the shaft 46 is rotated in a

clockwise direction, the switches are opened in sequence from right to left in a reverse manner.

The windings of the motor 39 are controlled primarily by a proportioning type thermostatic controller 65 comprising a bimetal element 66 arranged to actuate a slider 67 which sweeps across a resistance 68 when the temperature affecting the element 66 rises and falls. The controller 65 is arranged to operate over a range of 2°, the slider 67 being at the upper end of resistance 68 when the temperature is 70° F., and being at the lower end of resistance 68 when the temperature rises to 72° F. The controller 65 controls the windings of the motor 39 through a mouse-trap relay 70 comprising a U-shaped armature 71 having legs 72 and 73, there being a winding 74 associated with leg 72 and a winding 75 associated with leg 73. The armature 71 is pivoted at 76 and it carries a switch blade 77 movable between fixed electrical contacts 78 and 79. When the windings 74 and 75 are equally energized, the magnetic pull exerted on legs 72 and 73 is equal and the armature assumes a balanced position wherein the switch blade 77 is equally distant between the contacts 78 and 79. When the energization of winding 74 preponderates over that of winding 75, the magnetic pull on leg 72 exceeds that on leg 73, and the armature 71 is rotated in a clockwise direction causing blade 77 to engage contact 78. When the energization of winding 75 preponderates over that of winding 74, the magnetic pull on leg 73 is greater than that on leg 72 and armature 71 is rotated in a counter-clockwise direction causing switch blade 77 to engage contact 79. The controls for the windings of motor 39 also include a rebalancing potentiometer comprising a resistance 81 having associated therewith a slider 82 which is mounted on a shaft 83 driven by the motor 39. In practice, the shaft 83 is driven through a gear train so as to operate at a slower speed than the shaft 42; the slider 82 may of course be mounted on the shaft 46.

Also mounted on the shaft 46 is a switch actuating finger 85 arranged to actuate limit switches 86 and 87, the limit switches 86 and 87 being in circuit with the windings 44 and 43, respectively, so as to interrupt the circuit through the motor windings whenever the shaft 46 has been driven to a limiting position in either direction. The switch 86 comprises blades 88 and 89 carrying contacts 90 and 91, respectively, which are normally in engagement, the blade 88 having an extending portion which may be engaged by the finger 85 for opening the switch 86 when the shaft 46 has been rotated substantially 180° in a counter-clockwise direction from the position in which it is shown on the drawings. Switch 87 comprises blades 93 and 94 carrying contacts 95 and 96, respectively, which are normally in engagement, the blade 93 having an extending portion which is adapted to be engaged by the finger 85 when the step controller is in initial position as shown for opening the switch 86.

Power for the proportioning control system is supplied by a step-down transformer 98 comprising a primary winding 99 and a secondary winding 100, the secondary winding having a fewer number of turns than the primary winding. Power is supplied to the primary winding through wires 101 and 102 connected to any suitable source of power not shown.

Numeral 103 designates a manual switch blade cooperating with a fixed electrical contact 104. This switch controls the winding 75 and, as will

presently be described, is operable to cause the step controller to return to initial position. The details of operation of the step controller in response to the proportioning controller 65 will be pointed out in the description of operation hereinafter wherein all of the various electrical circuits will be traced.

The controls for the various compressor motors include a power failure relay designated by the numeral 105, this relay having a winding 106 with which is associated an armature connected to switch blades 107 and 108 which are moved into engagement with fixed electrical contacts 109 and 110, respectively, when the winding is energized. The power failure relay 105 is normally energized as will presently be pointed out, and controls the power supplied to all of the compressor motors.

Numeral 115 designates another relay which, as will be presently pointed out, controls only the motor of compressor 19, the relay 115 comprises a winding 116 having an armature associated therewith connected to switch blades 117 and 118 which are moved to the left into engagement with fixed electrical contacts 119 and 120, respectively, by the armature when the winding 116 is energized.

Numeral 122 designates another relay which controls the relay 115, the relay 122 comprising a winding 123 having an armature associated therewith connected to a movable switch blade 124 which is moved to the left into engagement with the fixed electrical contact 125 by the armature when the winding 123 is energized.

The motor of compressor 19 is controlled by a relay or starter 125 comprising a winding 127 having an armature associated therewith connected to a movable switch blade 128, which is moved to the left into engagement with the fixed electrical contact 129 by the armature when the winding 127 is energized. The motors of compressors 20 and 21 are controlled by relays or starters 126a and 126b which are identical with the relay 126, the elements being similarly numbered with identifying characteristic letters a and b, so that further description of these relays is not necessary.

Numeral 131 designates a controller of a type disclosed in detail in the patent to Judson, No. 2,255,666. The controller 131 comprises a switch mechanism responsive to head pressure and suction pressure of the refrigeration system, the suction pressure responsive mechanism of the controller being connected to the pipe 30 by means of tubes 132 and 133. The head pressure responsive mechanism of the controller 131 is connected to the pipe 27 by a tube 134. The controller 131 is arranged to close the circuit therethrough when the suction pressure rises to a predetermined relatively high value and the head pressure falls to a predetermined relatively low value. The controller 131 is arranged to interrupt the circuit therethrough when the suction pressure falls to a predetermined relatively low value or when the head pressure rises to a predetermined relatively high value. Thus, the controller 131 acts as a limiting controller opening its circuit when the head pressure is relatively high to prevent overloading the compressor motors, it being understood that the controller 131 controls the supply of power to the compressor motors. The controller 131 also acts as a limit controller in that it cuts off the supply of power to the compressors when the suction pressure is relatively low and

closes the circuit to supply power only when the suction pressure rises to a relatively high value.

Numerals 136 designates a suction pressure responsive switch comprising an expansible bellows 137 connected to pipe 30 through tubes 133 and 138. The movable end of the bellows carries an operating stem into engagement with which a switch carrying lever 139 is normally urged by a coil spring 140. The lever 139 carries a mercury switch 141 having electrodes at its left end which become bridged when the suction pressure is above a predetermined relatively high value at which the bellows 137 is in an expanded position. When the suction pressure falls to a predetermined relatively low value, the bellows 137 contracts moving lever 139 in a clockwise direction and opens the switch 141.

With the parts in the position shown, the step controller 38 is in initial position, the temperature in space 12 being at a relatively low value of 70°, for example, at which cooling is not required and at which the slider 67 is at the upper end of resistance 68. The slider 82 of the rebalancing potentiometer is at the clockwise end of resistance 81. The valves 15 and 28 are closed, and inasmuch as the step controller is in initial position, the mercury switch 55 is closed so as to complete a circuit for the power failure relay 105 as follows: from line conductor 161 to wire 160, controller 131, wire 159, wire 158, mercury switch 55, wire 157, wire 156, wire 155, wire 154, winding 106, wire 153, wire 152, and wire 151 back to line conductor 150, the line conductors 150 and 161 being connected to any suitable source of power, not shown. When relay 105 is energized, blades 107 and 108 engage their respective fixed contacts, engagement of blade 108 with contact 110 completing a maintaining circuit for relay 105 which is independent of mercury switch 55, this circuit being as follows: from line conductor 161 to wire 160, controller 131, wire 159, wire 148, contact 110, blade 108, wire 149, wire 154, winding 106, wire 153, wire 152, and wire 151 back to line conductor 150. It is understood that the switch mechanism of controller 131 is in closed position, the suction pressure at this time being at a relatively high value and the head pressure being at a low enough value so as not to cause overloading of the compressor motors upon starting.

With the parts in the position shown, the windings 74 and 75 are equally energized so that the blade 77 is equally distant between contacts 78 and 79. The circuit for winding 74 is as follows: from the secondary 100 of transformer 98 to wire 162, wire 163, element 66, slider 67, wire 164, winding 74, wire 165, resistance 81, slider 82, wire 166 and wire 167 back to secondary 100. The circuit for winding 75 is as follows: from secondary 100 to wire 162, wire 163, element 66, slider 67, resistance 68, wire 169, contact 104, switch blade 103, wire 170, contact 109, switch blade 107, wire 171, winding 75, wire 172, slider 82, wire 166 and wire 167 back to secondary 100. Thus, it will be seen that all of resistance 81 is in series with winding 74 and all of resistance 68 is in series with winding 75. The values of the two resistances are equal and the two windings, being alike, they are equally energized so as to maintain the mouse-trap relay 70 in balanced position as shown. From the foregoing circuits, it will be seen that the winding 75 is controlled by the manual switch comprising blade 103 and also by one of the switches of relay 105. If the cir-

cuit of winding 75 should be interrupted by either of the said switches the energization of winding 74 would of course preponderate, unbalancing the relay 70 in a clockwise direction so as to cause blade 77 to engage contact 78. This would cause the step controller to return to an initial position as will presently be described.

It will now be assumed that there is an increase in the cooling load and that the temperature in the space 12 rises from 70° to 72° so that the slider 67 is gradually moved downwardly from the upper end of resistance 68 to its lower end. As the slider 67 moves downwardly, the resistance in circuit with winding 75 is obviously decreased so as to increase the energization of this winding to unbalance the relay 70 in a counter-clockwise direction bringing blade 77 into engagement with contact 79. This completes a circuit for motor winding 44 as follows: from secondary 100 through wire 62, wire 175, blade 77, contact 79, wire 176, switch 86, wire 177, winding 44, wire 178 and wire 167 back to secondary 100. Energization of motor winding 44 causes the motor 39 to rotate shaft 46 in a counter-clockwise direction. Upon shaft 46 being thus rotated, cam 47 causes mercury switch 55 to open but relay 105 remains energized through the above described maintaining circuit. When the temperature has risen to 70.5°, cam 48 closes mercury switch 60 which completes a circuit for energizing and opening valve 15 and admitting cold water to the coil 13, this circuit being as follows: from line conductor 161, to wire 160, controller 131, wire 159, wire 148, contact 110, switch blade 108, wire 149, wire 155, wire 156, wire 179, wire 180, mercury switch 60, wire 181, valve 15, wire 182, wire 152, and wire 151 back to line conductor 150.

It will be understood of course that as the motor 39 operates in the manner above described, the slider 82 of the rebalancing potentiometer is rotated in a counter-clockwise direction so as to reduce the amount of resistance in circuit with winding 74 so as to increase its energization to make it equal to that of winding 75 so as to rebalance the relay 70, the relay 70 being balanced when the temperature is stable and the step controller 38 assuming a position corresponding to the controller 65.

Upon a continued rise in temperature, cam 49 will next close mercury switch 61 which will energize relay 122 through the following circuit: from line conductor 161 through wire 160, controller 131, wire 159, wire 148, contact 110, switch blade 108, wire 149, wire 155, wire 156, wire 179, wire 185, wire 186, mercury switch 61, wire 187, wire 188, wire 189, winding 123, wire 190, wire 191, wire 192, and wire 151 back to line conductor 150. At the same time as relay 122 is energized, a circuit is completed for the solenoid valve 28 as follows: from line conductor 161 through wire 160, controller 131, wire 159, wire 148, contact 110, switch blade 108, wire 149, wire 155, wire 156, wire 179, wire 185, wire 186, mercury switch 61, wire 187, wire 193, valve 28, wire 194, wire 191, wire 192, and wire 151 back to line conductor 150. When relay 122 is energized, blade 124 moves into engagement with contact 125 completing a circuit for energizing relay 115 as follows: from line conductor 161, to wire 160, controller 131, wire 159, wire 148, contact 110, switch blade 108, wire 149, wire 155, wire 156, wire 179, wire 185, wire 186, mercury switch 61, wire 187, wire 188, wire 195, contact 125, switch

blade 124, wire 196, winding 116, wire 197, wire 192, and wire 151 back to line conductor 150.

When relay 115 is energized, blades 117 and 118 move into engagement with their respective contacts, engagement of blade 117 with contact 119 completing a maintaining circuit for winding 116 as follows: from line conductor 161, through wire 160, controller 131, wire 159, wire 148, contact 110, blade 108, wire 149, wire 155, wire 198, wire 199, contact 119, blade 117, wire 200, mercury switch 141 (which will be closed at the time due to relatively high suction pressure), wire 201, winding 116, wire 197, wire 192, and wire 151 back to line conductor 150. Engagement of blade 118 with contact 120 completes a circuit for starter 126 as follows: from line conductor 161, through wire 160, controller 131, wire 159, wire 148, contact 110, blade 108, wire 149, wire 155, wire 198, wire 202, contact 120, blade 118, wire 203, winding 126, and wire 204 back to line conductor 150. When starter 126 is energized, a circuit is completed for the motor of compressor 19 as follows: from line conductor 161, through wire 205, the motor of compressor 19, wire 206, contact 129, blade 128, wire 207 back to line conductor 150.

From the foregoing, it is to be seen that closure of mercury switch 61 causes opening of solenoid valve 28 and starting of compressor 19 so that the refrigeration system operates with refrigerant being supplied by a single compressor. It is to be noted also that power for the starter 126 for compressor 19 is supplied through the power failure relay 105 and relay 115 after this relay becomes energized, that is, the power supply for starter 126 is not dependent upon the step controller 38.

If the temperature continues to rise, cam 50 will close mercury switch 62 completing a circuit for starter 126a as follows: from line conductor 161 through wire 160, wire 159, wire 148, contact 110, blade 108, wire 149, wire 155, wire 156, wire 179, wire 185, wire 210, wire 211, mercury switch 62, wire 212, winding 127a and wire 213 back to line conductor 150. When starter 126a is energized, blade 128a moves into engagement with contact 129a completing a circuit for the motor of compressor 20 as follows: from line conductor 161 through wire 214, the motor of compressor 20, wire 215, contact 129a, blade 128a, and wire 216 back to line conductor 150.

If the load is such that even after compressor 20 is started the temperature continues to rise, slider 67 will eventually be moved to the bottom of resistance 68, and at this time mercury switch 63 will be closed, closure of this switch completing a circuit for starter 126b as follows: from line conductor 161, wire 160, controller 131, wire 159, wire 148, contact 110, blade 108, wire 149, wire 155, wire 156, wire 179, wire 185, wire 210, wire 217, switch 63, wire 218, winding 127b, wire 219 back to line conductor 150. When starter 126b is energized, blade 128b engages contact 129b and a circuit for the motor of compressor 21 is completed as follows: from line conductor 161 to the motor of compressor 21, through wire 220, contact 129b, blade 128b, to line conductor 150.

As pointed out, when all the mercury switches have been closed, slider 67 is at the bottom of the resistances, and at this time the slider 32 of the rebalancing potentiometer will be at the counter-clockwise end of resistance 81 and thus all of resistance 68 will be in circuit with winding 74 and all of resistance 81 will now be in cir-

cuit with winding 75. Under these circumstances, the finger 85 will have been rotated to a position wherein the limit switch 86 is open.

With all the compressors in operation, the refrigerative capacity is such that the temperature will now in all likelihood fall, and as it falls, the slider 67 is moved upwardly along resistance 60 so as to now decrease the amount of resistance in circuit with winding 74 so as to increase the energization of this winding so that it preponderates over that of winding 75. Thus relay 70 is unbalanced in a clockwise direction bringing blade 77 into engagement with contact 78 and completing a circuit for motor winding 43 as follows: from secondary 100 through wire 162, wire 175, blade 77, contact 78, wire 225, limit switch 87, wire 226, winding 43, wire 178, and wire 167 back to secondary 100. Motor 39 will now operate to rotate shaft 46 in a clockwise direction and the mercury switches will be opened in sequence from right to left as the temperature falls back to 70°. As the temperature falls, starter 126b will first be deenergized stopping compressor 21, and starter 126a will then be deenergized stopping compressor 20. Similarly, opening of mercury switch 61 will deenergize relay 122 and will deenergize the solenoid valve 28. However, relay 115 will remain energized through its maintaining circuit and will maintain the starter 126 of compressor 19 in energized position. When solenoid valve 28 is closed, no more refrigerant will be admitted to the evaporator, and with the compressor 19 still in operation the pressure in the evaporator will be pumped down relatively quickly to the value at which controller 136 opens its switch. When mercury switch 141 opens, the maintaining circuit for relay 115 is interrupted deenergizing this relay and causing deenergization of starter 126 and stoppage of compressor 19.

From the foregoing, it is to be seen that starting of compressor 19 is controlled by the step controller but that this compressor does not stop until the pressure in the evaporator has been pumped down.

If at any time during operation there is a failure of power supply, for instance, a momentary power failure, the power failure relay 105 will of course be deenergized as will all the other relays. The step controller may perhaps be in an intermediate position at this time with mercury switch 55 open, and when the power comes back on the power failure relay 105 will not be immediately reenergized because mercury switch 55 is open and the maintaining circuit has been interrupted. When relay 105 is deenergized upon the power failure, blade 107 disengages from contact 109 interrupting the circuit of winding 75 of relay 70. Thus, when the power supply is resumed the energization of winding 74 will preponderate over that of winding 75 which is completely deenergized and the step controller will recycle, that is, motor 39 will rotate shaft 46 in a clockwise direction and it will return to initial position wherein mercury switch 55 is closed and the power failure relay 105 will be reenergized through the circuit above described extending through mercury switch 55. When relay 155 has been deenergized as a result of a power failure, upon the power being resumed, power will not immediately be supplied to relay 115 because blade 108 will be disengaged from contact 110. Therefore, the relay 105 provides power failure protection for the first compressor 19 as well as

for the other compressors which are dependent entirely upon the step controller for power supply. By reason of the power failure protection arrangement, upon a failure of power supply, the control mechanism will recycle when power returns and the sequence will be started over again, the mechanism of course assuming a position dependent upon the position of the controller 65 at the time.

If it is desired to shut down the system manually, the manual switch blade 103 may be disengaged from contact 104 which will entirely interrupt the circuit of winding 75 so that the energization of winding 74 preponderates, unbalancing the relay 70 in a clockwise direction and causing motor 39 to operate in a direction to return the step controller to initial position. By thus shutting down the system manually in this manner, the power supply controlled by the power failure relay 105 is not cut off and thus relay 115 will remain energized keeping compressor 19 in operation until the evaporator is pumped down to the proper pressure. If manual shut down were accomplished merely by cutting off the power supply to the entire setup, all of the compressors would of course be immediately de-energized and pump-down of the evaporator would not be obtained.

From the foregoing, those skilled in the art will appreciate that I have provided a novel arrangement whereby a plurality of compressors may be controlled by a step controller and, while power failure protection is provided at all times, one compressor will always pump down the evaporator when operation of the refrigerating system is not required. Moreover, upon a manual shut down, one of the compressors will pump down the evaporator in the same manner.

Referring to Figure 2 of the drawings, I have shown another form of my invention wherein a single compressor is used and wherein the control arrangement provides for starting the compressor only when there is a demand by the thermostat and causing the compressor to pump down the evaporator each time that the thermostat becomes satisfied. Referring to Figure 2, numeral 240 designates a compressor driven by an electric motor, the compressor discharging into a condenser 241 through a pipe 242. The condenser is connected to an evaporator 243 by a pipe 244 and the outlet of the evaporator is connected to the suction inlet of the compressor by a pipe 245. Disposed in the pipe 244 is a solenoid type stop valve 246, and also interposed in the pipe 244 is a thermostatic expansion valve 247. The valve 247 is of the usual type adapted to maintain a predetermined degree of superheat at the outlet of the evaporator. The valve 247 includes an expansible operating chamber which is connected to a thermal bulb 248 by a capillary tube 249, the bulb 248 containing a vaporizable liquid and being disposed in intimate heat exchange relationship with the pipe 245. The liquid in the bulb 248 vaporizes and develops a pressure for actuating the valve depending upon the temperature in the pipe 245. The operation of this type of valve is well known in the art.

The compressor motor is controlled primarily by a thermostat 252 responsive to the temperature of a medium, for instance, air being cooled by the evaporator 243. The thermostat 252 comprises a bimetal element 253 arranged to actuate a movable switch blade 254 which is moved to the left into engagement with a fixed electrical contact 255 when the temperature affecting the

thermostat rises to a predetermined value which may be 72° F. for example. Associated with the blade 254 which is constructed so as to serve as an armature is a permanent magnet 256 so disposed as to cause the blade 254 to engage with and disengage from the contact 255 with a snap action in a manner well known in the art. The thermostat 252 may have a differential of 2°, for example, that is, opening at a temperature of 70° F.

The thermostat 252 controls a relay 258 comprising a winding 259 having an armature associated therewith which is connected to a movable switch blade 260 which is moved to the left by the armature into engagement with a fixed electrical contact 261 when the winding 259 is energized.

Power for operation of the relay 258 and the valve 246 is supplied by a step down transformer 262 comprising a primary winding 263 and a secondary winding 264 having a fewer number of turns than the primary. Power is supplied to the primary winding through wires 265 and 266 which may be connected to any suitable source of power not shown.

The relay 258 controls another relay or starter 269 comprising a winding 270 having an armature associated therewith connected to movable switch blades 271 and 272 which are moved to the left by the armature into engagement with fixed electrical contacts 273 and 274 respectively when the winding 270 is energized. Power for operation of the relay 269 is supplied by stepdown transformer 276 having a primary winding 277 and a secondary winding 278 having a fewer number of turns. Power may be supplied to the primary winding 277 through wires 279 and 280 which may be connected to the above referred to power source. One of the switches operated by relay 269 controls the motor of compressor 240 as will presently be described and the other controls a maintaining circuit for the winding 270 which maintaining circuit is controlled by a suction pressure controller designated by the numeral 282. The controller 282 comprises an expansible and contractible bellows 283, the interior of which is connected to the pipe 245 by a tube 284 so that the bellows expands and contracts in accordance with suction pressure of the compressor. The movable end of the bellows 283 carries an operating stem into engagement with which a pivoted switch carrying lever 285 is normally urged by a coil spring 286. The lever 285 carries a mercury switch 287 having electrodes at its left end which are engaged when the suction pressure is at or above a predetermined relatively high value, at which the bellows 283 is expanded, with the lever 285 in a position such as that shown in the drawings. When the suction pressure falls to a predetermined relatively low value, the bellows 283 contracts moving lever 285 in a clockwise direction and opening a switch 287.

In operation, when the temperature affecting thermostat 252 rises to the predetermined value of 72° F., for example, blade 254 engages contact 255 completing a circuit for energizing and opening solenoid valve 246 and completing another circuit for the relay 258, the circuit for the valve 246 being as follows: from the secondary 264 of transformer 262 through wire 289 to valve 246, wire 290, wire 291, contact 255, blade 254, element 253 and wire 292 to secondary 264. The circuit for relay 258 is as follows: from secondary 264 through wire 293, winding 259, wire 294, wire 291, contact 255, blade 254, element 253 and wire 292 back to secondary 264. When relay 258 is en-

energized, a circuit is completed for relay 269 as follows: from secondary 278 of transformer 276, through wire 299, switch 287, wire 300, wire 295, switch blade 260, contact 261, wire 296, wire 297, winding 270, wire 298 back to secondary 278. Completion of this circuit energizes the relay 269 moving switch blades 271 and 272 into engagement with their respective contacts, energizing the motor of compressor 240 and completing a maintaining circuit for relay 269. The maintaining circuit for relay 269 is as follows: from secondary 278 through wire 299, mercury switch 287, (which will normally be closed at the time) wire 300, wire 306, switch blade 272, contact 274, wire 301, wire 297, winding 270, and wire 298 back to secondary 278. The circuit for the motor of compressor 240 is as follows: from wire 279 to wire 302, switch blade 271, contact 273, wire 303, the motor of compressor 240, wire 304 back to wire 280, the wires 279 and 280 being connected to a suitable source of power as pointed out above.

Upon completion of the circuits described, the solenoid valve 246 will be opened and the compressor 240 will operate to produce refrigeration in the evaporator 243. By reason of the maintaining circuit for relay 269, the compressor motor will remain energized until the suction pressure falls to a low enough value to cause the mercury switch 287 to open, that is, the compressor will remain in operation until mercury switch 287 opens, even though the temperature of the air falls to a low enough value to cause thermostat 252 to open its contacts. When the thermostat 252 has opened its contacts and the suction pressure has fallen to a low enough value to open mercury switch 287, relay 269 will be deenergized and the compressor will be stopped. Of course, after the thermostat 252 has opened its contacts, the solenoid valve 246 will be closed cutting off the supply of refrigerant to the evaporator, and thereafter the compressor will pump the evaporator down to the setting of controller 282 relatively quickly. If during the time that the thermostat 252 is satisfied, the pressure in the evaporator should rise to the setting of controller 282 due to leakage past the valve 246 or the like, the compressor motor will not be energized because the controller 282 controls only the maintaining circuit of relay 269 and is not operable to energize this relay but only to deenergize it after the relay 269 has been deenergized. Thus, when the thermostat 252 becomes satisfied, the evaporator is always pumped down and thereafter the compressor is maintained inoperative until the thermostat 252 again calls for operation of the compressor. Thus, the system provides for pumping down of the evaporator and positive disconnection of the compressor motor until there is another demand for the refrigeration.

The embodiments of my invention which I have disclosed are representative of its preferred forms, it being understood that various modifications and variations in the invention will occur to those skilled in the art. My disclosure is to be interpreted in an illustrative rather than a limiting sense, and the invention is to be limited only in accordance with the claims appended hereto.

I claim as my invention:

1. In apparatus of the character described, in combination, a plurality of electrical devices to be controlled, an electrical control device having

a plurality of positions including an initial position for sequentially controlling said first devices, control means for normally controlling said control device, said means being so arranged that upon failure of power supply said means assumes a position wherein said control device assumes its initial position upon resumption of the power supply, and separate means for automatically controlling one of said first devices.

2. In apparatus of the character described, in combination, a plurality of electrical devices to be controlled, an electrical control device having a plurality of positions including an initial position for sequentially controlling said first devices, control means for normally controlling said control device, said means being so arranged that upon failure of power supply said means assumes a position wherein said control device assumes its initial position upon resumption of the power supply, and separate means for automatically controlling one of said first devices, said last means being controlled by said aforementioned means.

3. A refrigeration system comprising, in combination, a refrigerant translating device, an evaporator, means responsive to a condition of treated air, first relay means controlled by said condition responsive means, second relay means controlled by said first relay means and arranged to control said compressor, means forming a maintaining circuit for said second relay means for keeping it in a position causing operation of the translating device, and means responsive to evaporator pressure controlling said maintaining circuit arranged to interrupt said circuit at a predetermined evaporator pressure.

4. A refrigeration system comprising, in combination, a plurality of refrigerant translating devices, an evaporator, a step controller controlling said devices, means responsive to a condition of treated air controlling said step controller, and control means for maintaining one translating device in operation after it would otherwise be shut down by the step controller until a predetermined evaporator pressure is reached.

5. In a refrigeration system, a plurality of refrigerant translating devices, an evaporator, a step controller controlling said devices, means responsive to a condition of treated air controlling said step controller, and control means for maintaining one translating device in operation after it would otherwise be shut down by the step controller until a predetermined evaporator pressure is reached, said control means comprising a relay controlling said one translating device, circuit means whereby said relay is energizable by the step controller for starting said one translating device, means forming a maintaining circuit for said relay, and a device responsive to evaporator pressure controlling the maintaining circuit.

6. In a refrigeration system, a plurality of refrigerant translating devices, an evaporator, a step controller controlling the devices, normally energized relay means controlling the power supply to the step controller, means including a device responsive to suction pressure controlling one translating device to cause it to pump down the evaporator after the step controller has assumed a position not demanding operation of any translating devices, and means associated with the relay and step controller so arranged that if the relay is de-energized upon a power failure, upon the return of power, the step controller will operate to initial position.

7. A refrigeration system comprising, in combination, a plurality of refrigerant translating devices; an evaporator; a step controller controlling said devices, said step controller having a plurality of positions including an initial position; means comprising a normally energized relay controlling the supply of power to the step controller and translating devices, said relay and step controller being so related that the step controller must be in initial position to initially energize the relay; control means including a suction pressure responsive device so arranged that one device, after having been put in operation by the step controller, remains in operation until the evaporator is pumped down to a predetermined pressure even though the step controller moves to a position not demanding operation of any of the translating devices, and means associated with said relay and so related to said step controller that if the relay is deenergized as a result of a power failure, upon resumption of the power supply the step controller will return to initial position thereupon re-energizing the relay.

8. A refrigeration system comprising, in combination, a plurality of refrigerant translating devices; an evaporator; a step controller controlling said devices, said step controller having a plurality of positions including an initial position; means comprising a normally energized relay controlling the supply of power to the step controller and translating devices, said relay and step controller being so related that the step controller must be in initial position to initially energize the relay; a second relay energizable by said step controller for starting one translating device, means forming a maintaining circuit for said second relay whereby said one device is kept in operation to pump down the evaporator after the step controller moves to a position not demanding operation of any of the translating devices; means responsive to evaporator pressure arranged to interrupt said maintaining circuit at a predetermined pressure; means associated with said first relay and so related to said step controller that if the first relay is de-energized as a result of a power failure, upon resumption of the power supply the step controller will return to initial position thereupon re-energizing the first relay, and means whereby said first relay controls said maintaining circuit so that after a power failure said second relay cannot be re-energized until the step controller returns to initial position.

9. A refrigeration system comprising, in combination, a refrigerant translating device, an evaporator, means controlling the device comprising a relay and a control instrument responsive to a condition of medium treated by the evaporator, means forming a maintaining circuit for the relay, and means responsive to evaporator pressure controlling the maintaining circuit to cause the translating device to pump down the evaporator after the demands of the control instrument have been satisfied.

10. A refrigeration system comprising, in combination, a plurality of refrigerant translating devices, an evaporator, a step controller for sequentially starting the translating devices, means controlling one translating device for causing it to pump the evaporator down to a predetermined pressure when the system is shut down, and manual means for shutting down the system, said last means being so related to the step controller that upon a manual shut-down the step control-

ler returns to initial position and the said one translating device pumps down the evaporator.

11. In a refrigeration system, a plurality of translating devices, an evaporator, a step controller controlling said devices, means responsive to a condition of treated air controlling said step controller, and control means for maintaining one translating device in operation after it would otherwise be shut down by the step controller until a predetermined evaporator pressure is reached, said control means comprising a relay controlling said one translating device, circuit means whereby said relay is energizable by the step controller for starting said one translating device, means forming a maintaining circuit for said relay, a device responsive to evaporator pressure controlling the maintaining circuit, and manual shut-down means whereby upon a manual shut down the step controller moves to a position interrupting the initial energizing circuit of the relay, but the relay remaining energized through its maintaining circuit until the said predetermined evaporator pressure is reached.

12. In a refrigeration system comprising an evaporator and a plurality of compressors for feeding liquid refrigerant thereto, in combination; valve means controlling the supply of refrigerant to said evaporator; means responsive to the demand for refrigeration; means controlled thereby for opening said valve means and energizing a first of said compressors when said demand is relatively small; means controlled by said responsive means for successively energizing the other of said compressors as said demand increases, said responsive means acting through said controlled means to successively deenergize the other of said compressors and finally close said valve means as said demand becomes satisfied, and means responsive to evaporator pressure for maintaining said first compressor energized until said pressure decreases to a predetermined value.

13. In a refrigeration system comprising an evaporator and a plurality of compressors for feeding liquid refrigerant thereto; in combination, valve means controlling the supply of refrigerant to said evaporator; means responsive to the demand for refrigeration; means controlled thereby for opening said valve means and energizing a first of said compressors when said demand is relatively small; means controlled by said responsive means for successively energizing the other of said compressors as said demand increases, and means responsive to a power failure and operative upon a resumption of power to cause said controlled means to return to the position which they would normally occupy when there is no demand for refrigerant, and thereafter energize said compressors successively to supply sufficient refrigerant to meet the demand for refrigeration.

14. In a refrigeration system comprising an evaporator and a plurality of compressors for feeding liquid refrigerant thereto; in combination, valve means controlling the supply of refrigerant to said evaporator; means responsive to the demand for refrigeration; means controlled thereby for opening said valve means and energizing a first of said compressors when said demand is relatively small; means controlled by said responsive means for successively energizing the other of said compressors as said demand increases, said responsive means acting through said controlled means to successively deenergize

the other of said compressors and finally close said valve means as said demand becomes satisfied; means responsive to evaporator pressure for maintaining said first evaporator energized until said pressure decreases to a predetermined value, and means responsive to a power failure and operative upon a resumption of power to cause said controlled means to return to the position which they would normally occupy when there is no demand for refrigerant, and thereafter energize said compressors successively to supply sufficient refrigerant to meet the demand for refrigeration.

15. In a refrigerating system comprising, in combination, a refrigerant translating device, a condenser, evaporator means, said translating device, when operating, causing refrigerant flow through said condenser to said evaporator means, suction means connecting the outlet of said evaporator means to the inlet of said translating device, means responsive to a condition of a medium being treated by said evaporator means for starting the translating device, valve means controlling the flow of refrigerant from said condenser to said evaporator means, said valve means being capable of stopping all flow from said condenser, said condition responsive means being arranged to control said valve means to stop all refrigerant flow from said condenser upon the condition responsive means becoming satisfied, and means responsive to suc-

tion pressure arranged to cause continued operation of the translating device after said condition responsive means is satisfied until a predetermined suction pressure is reached.

5 16. A refrigerating system comprising, in combination, a refrigerant translating device, a relay controlling said device, a condenser, evaporator means, operation of said translating device causing refrigerant flow through said condenser to
10 said evaporator means, suction means connecting the outlet of said evaporator means to the inlet of said translating device, means responsive to a condition of a medium being treated for actuating said relay and starting the translating
15 device, valve means controlling the flow of refrigerant from said condenser to said evaporator means, said valve means being capable of stopping all flow from said condenser, said condition responsive means being arranged to control said
20 valve means to stop all refrigerant flow from said condenser upon the condition responsive means becoming satisfied, means forming a maintaining circuit for said relay, and means responsive to suction pressure controlling said main-
25 taining circuit and so arranged that said translating device is kept in operation by reason of said maintaining circuit after the condition responsive means is satisfied until a predetermined relatively low suction pressure is reached.

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