

Aug. 6, 1940.

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2,210,325

REFRIGERATION CONTROL SYSTEM

Filed Feb. 20, 1939

3 Sheets-Sheet 1

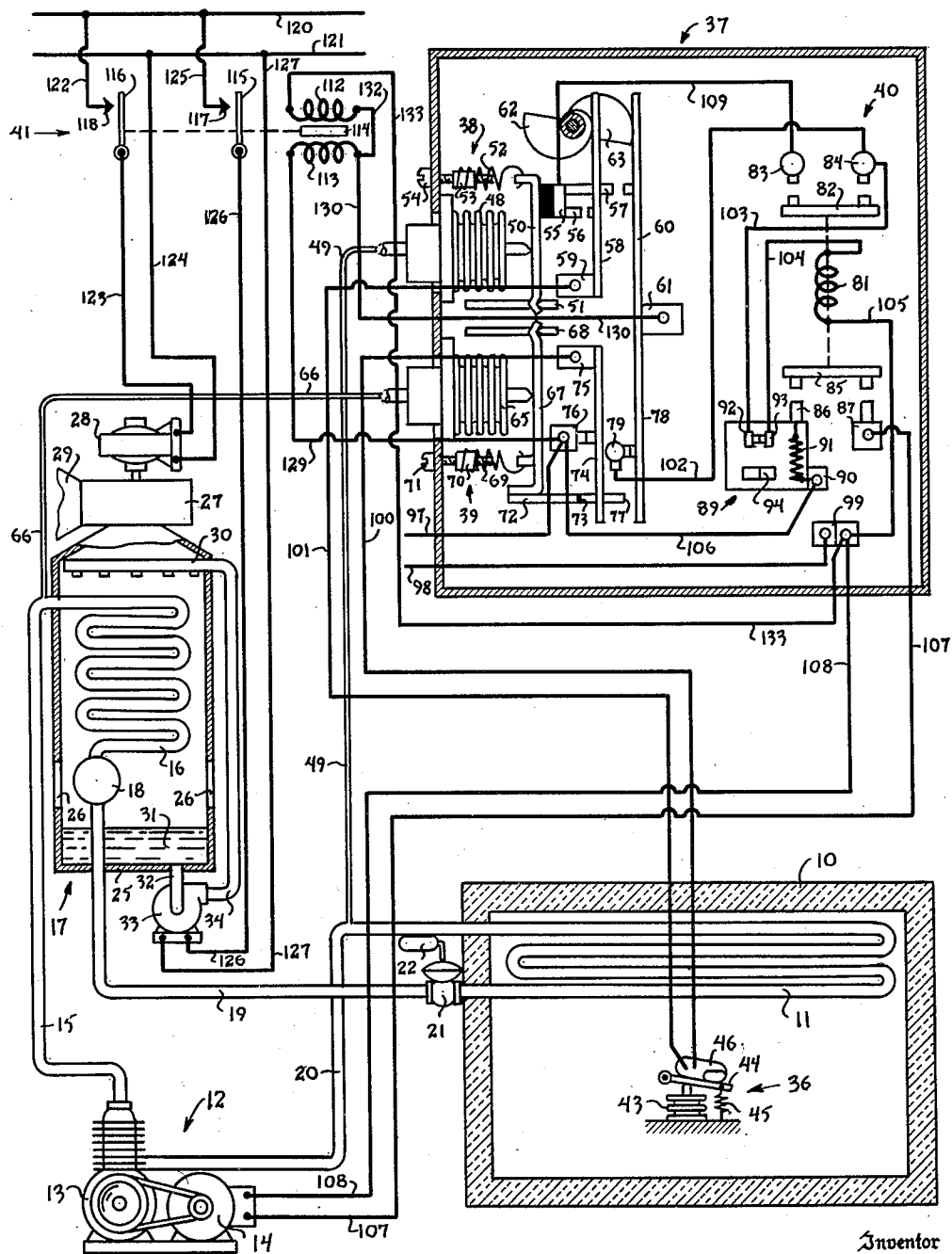


Fig. 1

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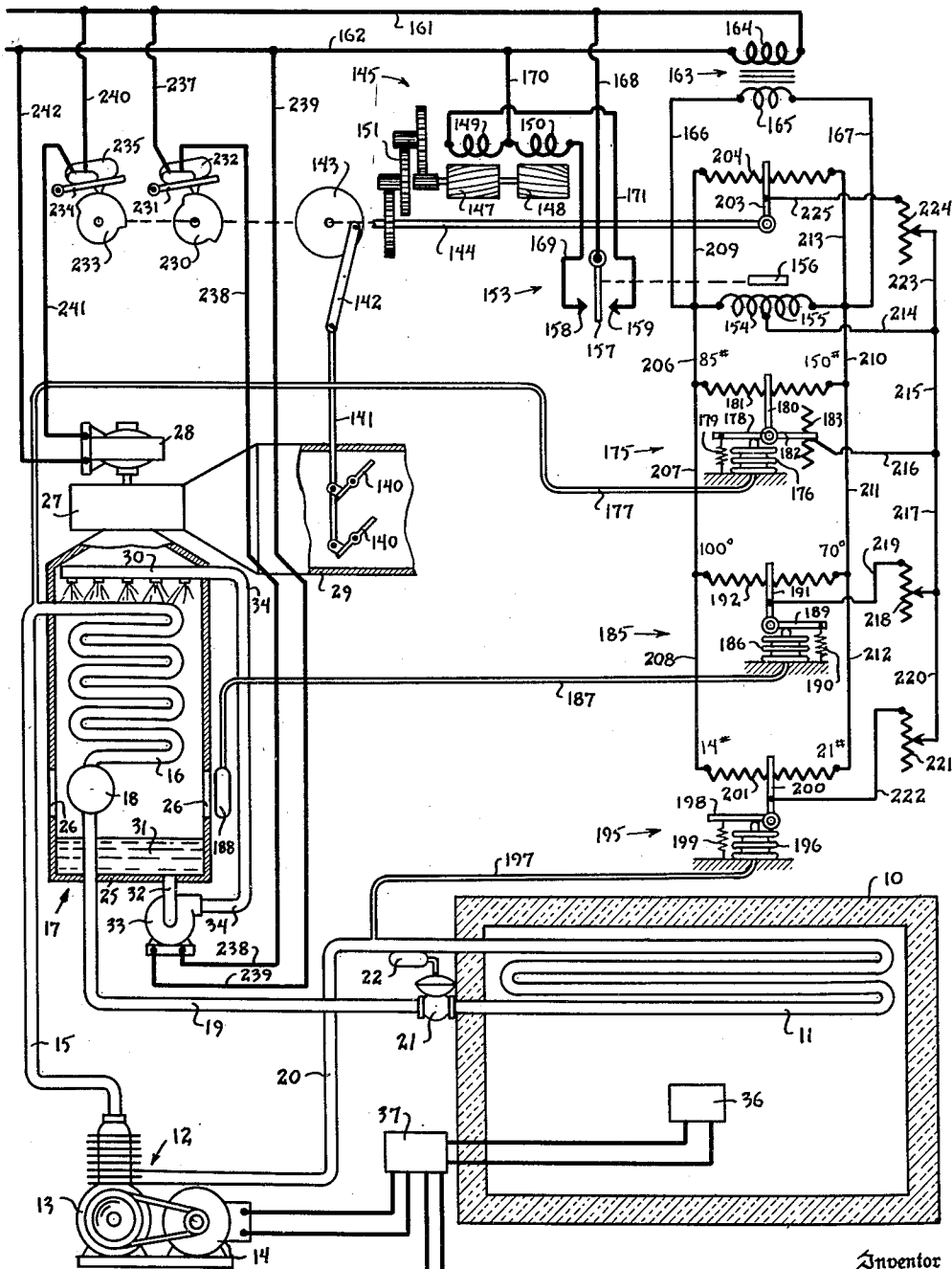


Fig. 2

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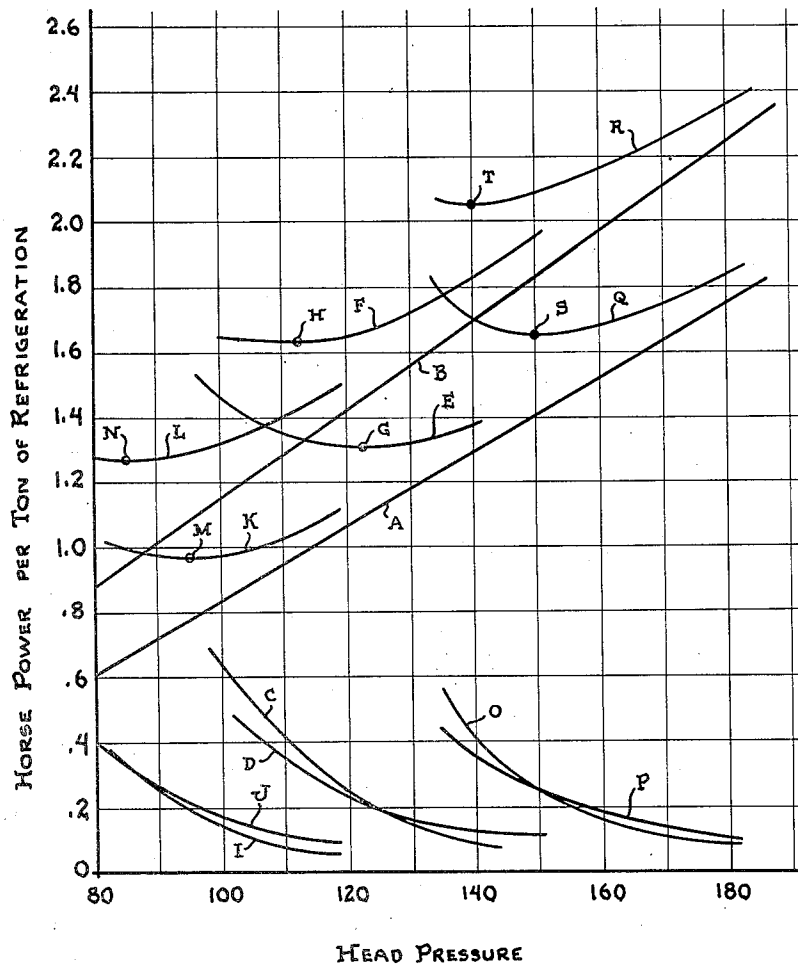


Fig. 3

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UNITED STATES PATENT OFFICE

2,210,325

REFRIGERATION CONTROL SYSTEM

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Application February 20, 1939, Serial No. 257,407

12 Claims. (Cl. 62-4)

This invention relates to control systems for a refrigerating apparatus provided with an evaporative condenser.

An object of this invention is to stop operation of the evaporative condenser of a refrigerating apparatus when the pressure on the high pressure side of the refrigerating apparatus decreases to a desired low value whereby needless operation of the evaporative condenser is prevented and circulation of refrigerant through the refrigerating apparatus is assured.

Another object of this invention is to control the operation of the evaporative condenser in accordance with the pressure on the high pressure side of the refrigerating apparatus to maintain the pressure on the high pressure side of the refrigerating apparatus within a desired range, and also to control the evaporative condenser in accordance with the temperature of the air entering the evaporative condenser to allow the desired range of pressure on the high pressure side of the refrigerating apparatus to rise as the temperature of the air increases. This maintains the total power consumption by the fan means of the evaporative condenser and the compressor at a minimum at all times.

Still another object of this invention is to additionally control the evaporative condenser in accordance with pressure on the low pressure side of the refrigerating apparatus to cause the pressure on the high pressure side of the refrigerating apparatus to decrease within the desired range as the pressure on the low pressure side of the refrigerating apparatus increases where fairly wide fluctuations in suction pressure are encountered. This also maintains the total power consumption by the fan means and the compressor at a minimum.

Other objects of this invention reside in the combination of elements for obtaining the desired sequence of operation as is more fully set forth in the specification, claims, and drawings, in which

Figure 1 is a diagrammatic illustration of one form of this invention, and

Figure 2 is a diagrammatic illustration of another form of this invention.

Figure 3 is a graph plotting horsepower per ton of refrigeration against head pressure of the refrigerating apparatus of Figure 2.

Referring now to Figure 1 a medium to be cooled is enclosed in an enclosure 10. For purposes of illustration the medium is assumed to be air within a walk-in box 10 for commercial refrigeration work but also may be air within a space for air

conditioning work. The medium is cooled by means of a cooling coil taking the form of an evaporator 11. Refrigerant is supplied to and withdrawn from the evaporator 11 by means of a refrigerating apparatus generally designated at 12 which may comprise a compressor 13 operated by an electric motor 14. Compressed refrigerant passes from the compressor 13 through a high pressure line 15 to a coil 16 of an evaporative condenser generally designated at 17. Condensed refrigerant is collected from the coil 16 in a receiver 18 and the liquid refrigerant flows from the receiver 18 through a liquid line 19 to the evaporator 11. Evaporated refrigerant is withdrawn from the evaporator 11 through a suction or low pressure line 20 by the compressor 13. The supply of refrigerant to the evaporator 11 may be regulated by a thermostatic expansion valve 21 having a thermostatic bulb connected to the outlet of the evaporator 11. Since such a construction is conventional in the art a further description thereof is not considered necessary it being sufficient to state that when the compressor 13 is operating the evaporator 11 performs a cooling function.

The evaporative condenser 17 may comprise a casing 25 enclosing the condenser coil 16. The casing 25 is provided with air inlets 26 and air is drawn through the inlets 26 and over the condenser coil 16 by means of a fan 27 operated by an electric motor 28. Air is discharged from the fan 27 through a discharge duct 29. A spray 30 sprays water in contact with the air circulating in the casing 25 and in contact with the condenser coil 16, the water being collected in a sump 31. The water is withdrawn from the sump 31 through a pipe 32 by an electrically operated circulating pump 33 and delivered through a pipe 34 to the spray 30. The water contacting the air provides evaporative cooling for the condenser coil 16. Suitable means (not shown) for supplying water to the sump 31 to make up water lost during the evaporation process may be provided.

The operation of the compressor 13 and hence the refrigerating apparatus as a whole is controlled by a temperature responsive controller generally designated at 36 responsive to the temperature of the medium within the enclosure 10 and a unitary control arrangement generally designated at 37. The unitary control arrangement 37 comprises a control device 38 responsive to variations in pressure on the low pressure side of the refrigerating apparatus, a pressure responsive device 39 responsive to the pressure on the high pressure side of the refrigerating apparatus and a

relay or starter generally designated at 40. The arrangement of the parts are such that upon a call for cooling by the temperature responsive controller 36 the refrigerating apparatus cannot be placed in operation until the pressure on the high pressure side of the refrigerating apparatus decreases to a predetermined low value and the pressure on the low pressure side of the refrigerating apparatus increases to a predetermined high value, which for example may be a defrosting value. The compressor is then maintained in operation until either the demand for cooling is satisfied, or the pressure on the high pressure side of the refrigerating apparatus increases to a predetermined high value, or the pressure on the low pressure side of the refrigerating apparatus decreases to a predetermined low value.

The fan 28 and the water circulating pump 33 of the evaporative condenser 17 are controlled by a relay generally designated at 41, the relay 41 in turn being controlled by the unitary control arrangement 37. The arrangement is such that the fan 28 and water circulating pump 33 are stopped and hence the evaporative condenser is rendered inoperative when the pressure on the high pressure side of the refrigerating apparatus decreases to a predetermined low value which for example may be the value which permits starting of the compressor.

The temperature responsive controller 36 may comprise a bellows 43 charged with a volatile fluid for operating a lever 44 against the action of an adjustable tension spring 45 for in turn operating a mercury switch 46. For purposes of illustration it is assumed that the parts are so arranged that when the temperature of the medium within the enclosure 10 rises to 42° the mercury switch 46 is tilted to a closed position and when the temperature within the enclosure decreases to 40° the mercury switch 46 is tilted to the open position.

The pressure responsive device 38 of the unitary control arrangement 37 may comprise a bellows 48 connected by a pipe 49 to the low pressure or suction line 20. The bellows 48 operates a lever 50 pivoted at 51 against the action of an adjustable tension spring 52. One end of the spring 52 is connected to the lever 50 and the other end is connected to a nut 53 screw threadedly mounted on a screw 54. By rotating the screw 54 the tension in the spring 52 may be varied to adjust the pressure setting of the pressure responsive device 38. The lever 50 carries in an insulated manner a bridge member 55 provided with contacts 56 and 57. The contact 56 engages a contact member 58 mounted on a terminal post 59 and the contact 57 engages a contact member 60 mounted on a terminal post 61. Concentrically located cams 62 and 63 are utilized for independently positioning the contact members 58 and 60. For purposes of illustration it is assumed that upon an increase in pressure on the low pressure side of the refrigerating apparatus the contact 56 first engages the contact member 58 at 10 lbs. and then the contact 57 engages the contact member 60 at 35 lbs. Upon a decrease in suction pressure the contact 57 first disengages the contact member 60 at 35 lbs. and the contact 56 disengages the contact member 58 at 10 lbs.

The pressure responsive device 39 of the unitary control arrangement 37 may comprise a bellows 65 connected by a pipe 66 to the high pressure line 15 of the refrigerating apparatus.

The bellows 65 operates a lever 67 pivoted at 68 against the action of an adjustable tension spring 69. One end of the spring 69 is connected to the lever 67 and the other end is connected to a nut 70 screw threadedly mounted on a screw 71. By rotating the screw 71 the tension in the spring 69 is varied to adjust the pressure setting of the pressure responsive device 39. The lever 67 carries an abutment member 72 preferably made of insulating material and provided with abutments 73 and 77. The abutment 73 is adapted to engage a contact member 74 carried by a terminal post 75 to separate the contact member 74 from a contact 76. The abutment 77 is adapted to engage a contact member 78 carried by the terminal post 61 to cause the contact member 78 to disengage a contact 79. For purposes of illustration it is assumed that upon an increase in pressure on the high pressure side of the refrigerating apparatus contact member 78 first disengages contact 79 at 140 lbs. and the contact member 74 disengages contact 76 at 200 lbs. Upon a decrease in pressure on the high pressure side of the refrigerating apparatus contact member 74 first engages contact 76 at 200 lbs. and the contact member 78 engages contact 79 at 140 lbs.

The relay or starter 40 may comprise an operating coil 81 for operating a bridge member 82 with respect to contacts 83 and 84 and a bridge member 85 with respect to contacts 86 and 87. When the operating coil 81 is energized the bridge member 82 engages the contacts 83 and 84 and the bridge member 85 engages contacts 86 and 87 and when the operating coil 81 is deenergized the bridge members 82 and 85 disengage their respective contacts by means of springs gravity or other means (not shown).

If desired the unitary control arrangement 37 may be provided with an overload cut-out generally designated at 89. This overload cut-out may comprise a heater element 91 connected between a terminal 90 and the contact 86. The heater element affects a thermostatic latch mechanism for separating contacts 92 and 93 when the current flow through the heater element 91 becomes excessive. The latch mechanism may be manually reset to reclose the control contacts 92 and 93 following separation of these contacts upon an overload condition. Power is supplied to the compressor motor 14 and to the unitary control arrangement 37 by means of line wires 97 and 98 leading from some source of power (not shown), the line wire 97 being connected to the contact 76 and the line wire 98 being connected to a terminal 99.

For a more detailed description of the construction of the unitary control arrangement 37 reference is made to application Serial No. 196,447 filed March 17, 1938 by Albert L. Judson and Carl G. Kronmiller.

Assume now that the temperature within the enclosure 10 increases to 42° to close the mercury switch 46, that the pressure on the high pressure side of the refrigerating apparatus decreases to 140 lbs. to cause contact member 74 to engage contact 76 and contact member 78 to engage contact 79 and that the pressure on the low pressure side of the refrigerating apparatus increases to 35 lbs. to cause contact 56 to engage contact member 58 and contact 57 to engage contact member 60. A circuit is thereupon completed from the line wire 97 through contact 76, contact member 74, terminal post 75, wire 100, mercury switch 46, wire 101, terminal post 59,

contact member 58, contact 56, bridge member 55, contact 57, contact member 60, contact member 78, contact 79, wire 102, contact 84, wire 103, contacts 92 and 93, wire 104, operating coil 81, wire 105, and terminal 99 back to the other line wire 98. Completion of this circuit energizes the operating coil 81 to move the bridge member 82 into engagement with contacts 83 and 84 and to move the bridge member 85 into engagement with contacts 86 and 87.

Movement of the bridge member 85 into engagement with the contacts 86 and 87 completes a load circuit for the compressor motor 14 which may be traced from the line wire 97 through contact 76, wire 106, terminal 90, heater element 91, contact 86, bridge member 85, contact 87, wire 107, compressor motor 14, wire 108 and terminal 99 back to the other line wire 98. Completion of this circuit causes operation of the compressor motor 14.

Movement of the bridge member 82 into engagement with the contacts 83 and 84 completes a maintaining circuit for the operating coil 81 which is independent of contact 57, contact members 60 and 78, and contact 79. This maintaining circuit may be traced from the line wire 97 through contact 76, contact member 74, terminal post 75, wire 100, mercury switch 46, wire 101, terminal post 59, contact member 58, contact 56, bridge member 55, wire 109, contact 83, bridge member 82, contact 84, wire 103, contacts 92 and 93, wire 104, operating coil 81, wire 105, and terminal 99 back to the other line wire 98. Completion of this circuit maintains the operating coil 81 energized and hence the refrigerating apparatus in operation until either the temperature within the enclosure 10 decreases to 40° to open the mercury switch 46 or the pressure on the high pressure side of the refrigerating apparatus increases to 200 lbs. to separate contact member 74 and contact 76 or until the pressure on the low pressure side of the refrigerating apparatus decreases to 10 lbs. to separate the contact member 58 and contact 56.

The relay 41 for controlling the operation of the fan 28 and the water circulating pump 33 may comprise relay coils 112 and 113 for operating an armature 114 which in turn operates switch arms 115 and 116 with respect to contacts 117 and 118. When either of the relay coils 112 or 113 are energized the switch arms 115 and 116 are moved out of engagement with their respective contacts 117 and 118 and when the relay coils 112 and 113 are deenergized or both coils 112 and 113 are simultaneously energized the switch arms 115 and 116 are moved into engagement with their respective contacts 117 and 118 by means of springs gravity or other means (not shown). Power is supplied to the fan 28 and the water circulating pump 33 by means of line wires 120 and 121 leading from some source of power (not shown). When the switch arm 116 engages contact 118 a circuit is completed from the line wire 120 through wire 122, contact 118, switch arm 116, wire 123, fan motor 28, and wire 124 back to the other line wire 121 to cause operation of the fan 27. Movement of the switch arm 115 into engagement with contact 117 completes a circuit from the line wire 120 through wire 125, contact 117, switch arm 115, wire 126, pump 37, and wire 127 back to the other line wire 121.

The relay coil 113 is connected by wire 129 to the contact 76 and by wire 130 to the terminal post 61. Relay coil 112 is connected by wire 130 and wire 132 to the terminal post 61 and by wire

133 to the terminal 99. By reason of these wiring connections it is seen that the relay coil 113 is connected in parallel with contact 76 and contact member 74, mercury switch 46, contact 56 and contact member 58, and contact 57 and contact member 60 and that relay coil 112 is connected in parallel with contact 79 and contact member 78, and operating coil 81. It is also seen that the relay coils 112 and 113 are connected in series at all times across the line wires 97 and 98. The polarity or impedance values of the relay coils 112 and 113 are such that when they are connected in series across the line wires 97 and 98 neither relay coil 112 nor 113 will be energized sufficiently to move the armature 114 towards the right so that under these conditions the relay 41 will remain dropped out.

Assume now that the operating coil 81 is deenergized by reason of the fact that one of the switches controlling the same is open, for example, the mercury switch 46 of the temperature controller 36, and accordingly the compressor 13 is stopped. If now the pressure on the high pressure side of the refrigerating apparatus decreases to 140 lbs. to move contact member 78 into engagement with contact 79, a circuit is completed from line wire 97 through contact 76, wire 129, relay coil 113, wire 130, terminal post 61, contact member 78, contact 79, wires 102 and 103, contacts 92 and 93, wire 104, operating coil 81, wire 105 and terminal 99 back to the line wire 98. Completion of this circuit energizes the relay coil 113 sufficiently to pull in the relay 41 to stop operation of the fan 27 and the water circulating pump 33. The impedance value of the relay coil 113 is such that the operating coil 81 is not energized sufficiently by this circuit to pull in its relay or starter. The relay coil 112 is substantially shorted out by this circuit so that the relay coil 113 can pull in the relay 41. Accordingly, when the compressor 13 is not operating and the pressure on the high pressure side of the refrigerating apparatus decreases to a predetermined low value, illustratively 140 lbs., the fan 27 and the pump 33 of the evaporative condenser 17 are stopped. When the various contacts and switches are closed to energize the operating coil 81, the relay coil 113 is substantially short-circuited so that it no longer influences the armature 114.

Assume now that the various contacts and switches close to energize the operating coil 81 to start the compressor 13 in the manner outlined above. Almost immediately following starting of the compressor 13 the suction pressure decreases sufficiently to move the contact 57 out of engagement with the contact member 60 but the compressor is maintained in operation by the above outlined maintaining circuit. As long as the pressure on the high pressure side of the refrigerating apparatus remains below 140 lbs. during operation of the compressor, a circuit is completed from the line wire 97 through contact 76, contact member 74, terminal post 75, wire 100, mercury switch 46, wire 101, terminal post 59, contact member 58, contact 56, bridge member 55, wire 109, contact 83, bridge member 82, contact 84, wire 102, contact 79, contact member 78, terminal post 61, wires 130 and 132, relay coil 112, wire 133, and terminal 99 back to the line wire 98. Completion of this circuit energizes the relay coil 112 sufficiently to attract the armature 114 to stop operation of the fan 27 and the pump 33. As soon as the pressure increases above 140 lbs. to move contact member 78 out of engagement

with contact 79, this circuit is interrupted and the relay 41 drops out to start the fan 27 and the pump 33.

By reason of the above construction, the fan 27 and the pump 33 of the evaporative condenser 17 are stopped when the pressure on the high pressure side of the refrigerating apparatus decreases to a predetermined low value, illustratively 140 lbs., regardless of whether the compressor 13 is operating or not. This insures that the condenser will not be undercooled when the temperature of the air entering the evaporative condenser becomes low to insure that there will always be sufficient head pressure in the refrigerating system to cause circulation of refrigerant there-through. In addition to this beneficial feature needless operation of the evaporative condenser is prevented resulting in quite a saving from the standpoint of operating cost. The relay 41 may be of the heat operated type or equipped with a damping device, such as a dash-pot, for retarding the frequency of operation thereof.

Referring now to Figure 2 the same enclosure 10, refrigerating apparatus 12, and evaporative condenser 17 are utilized as are utilized in Figure 1 and accordingly like reference characters for like parts have been set forth. The refrigerating apparatus 12 may be controlled in any suitable manner as far as this modification is concerned but for purposes of illustration it is shown to be controlled in the same manner as the refrigerating apparatus of Figure 1 is controlled by means of the temperature responsive controller 36 and the unitary control arrangement 37 to maintain desired temperature conditions within the enclosure 10.

Discharge duct 29 of the evaporative condenser 17 is provided with dampers 140 connected by an arm 141, and a pitman 142 to a crank disc 143 carried by a shaft 144. Shaft 144 is rotated by a motor 145 which may be of the proportioning type illustrated in Patent No. 2,028,110 granted to D. G. Taylor on January 14, 1936. For purposes of illustration in this application the motor 145 is shown to comprise rotors 147 and 148 operated by field windings 149 and 150. The motor rotors 147 and 148 rotate the shaft 144 in opposite directions through a reduction gear train 151, the arrangement being such that when the field winding 149 is energized the dampers 140 are moved towards a closed position and when the field winding 150 is energized the dampers 140 are moved towards an open position. The energizations of the field windings 149 and 150 are controlled by a relay generally designated at 153 which may comprise series connected relay coils 154 and 155 for operating an armature 156 which in turn operates a switch arm 157 with respect to contacts 158 and 159. Power is supplied to the motor 145 and to the relay 153 by means of line wires 161 and 162 leading from some source of power (not shown). A step-down transformer 163 has a primary 164 connected across line wires 161 and 162 and a secondary 165 connected by wires 166 and 167 to the ends of the series connected relay coils 154 and 155 for reducing the voltage of the relay control circuit. Accordingly it is seen that the relay coils 154 and 155 are connected in series across the source of power. When the relay coil 154 is more highly energized than the relay coil 155 the switch arm 157 is moved into engagement with the contact 158 to complete a circuit from the line wire 161 through wire 168, switch arm 157, contact 158, wire 169, field winding 150 and wire 170 back to the other

line wire 162 to energize the field winding 150 to move the dampers 140 towards an open position. When the relay coil 155 is more highly energized than the relay coil 154 the switch arm 157 is moved into engagement with the contact 159 to complete a circuit from the line wire 161 through wire 168, switch arm 157, contact 159, wire 171, field winding 149, and wire 170 back to the other line wire 162 to energize the field winding 149 to move the dampers 140 towards a closed position. When the relay coils 154 and 155 are equally energized the switch arm 157 is maintained spaced midway between the contacts 158 and 159 so that neither field winding 149 or 150 are energized to maintain the dampers 140 stationary.

The relay 153 is controlled by a pressure controller 175 responsive to the pressure on the high pressure side of the refrigerating apparatus which may comprise a bellows 176 connected by a pipe 177 to the high pressure line 15 for operating a lever 178 against the action of an adjustable tension spring 179. The lever 178 operates a slider 180 with respect to a resistance element 181 and a slider 182 with respect to a center tapped resistance element 183. The slider 180 and the resistance element 181 form a control potentiometer for the series connected relay coils 154 and 155 of the relay 153. For purposes of illustration it is assumed that the slider 180 assumes an extreme left hand position when the pressure on the high pressure side of the refrigerating apparatus decreases to 85 lbs. and assumes an extreme right hand position when the pressure on the high pressure side of the refrigerating apparatus assumes a value of 150 lbs. For intermediate pressure values the slider 180 assumes corresponding positions between the limits defined.

The relay 153 is also controlled by a temperature responsive controller generally designated at 185. This temperature responsive controller may comprise a bellows 186 connected by a capillary tube 187 to a bulb 188, the bulb 188 containing a volatile fluid so that the bellows 186 is operated in accordance with temperature changes. The bulb 188 is located in the path of the air entering the evaporative condenser 17 and usually this air is outside air. The bellows 186 operates a lever 189 against the action of a tension spring 190, the lever 189 in turn operating a slider 191 with respect to a resistance element 192. The slider 191 and resistance element 192 form a compensating potentiometer for shifting the control range of the pressure responsive controller 175. For purposes of illustration it is assumed that when the temperature of the air entering the evaporative condenser is at 70° the slider 191 assumes an extreme right hand position and as the air temperature increases from 70° the slider 191 is moved progressively towards the left until the temperature reaches 100° at which time the slider 191 assumes an extreme left hand position.

The relay 153 may also be controlled by a pressure responsive controller 195 responsive to pressure on the low pressure side of the refrigerating apparatus. The pressure responsive controller 195 may comprise a bellows 196 connected by a pipe 197 to the suction line 20 for operating a lever 198 against the action of an adjustable spring 199. The lever 198 operates a slider 200 with respect to a resistance element 201, the slider 200 and resistance element 201 forming a compensating potentiometer for shifting the control point of the pressure responsive controller 175 within the desired control range. For pur-

poses of illustration it is assumed that when the suction pressure is 21 lbs., the slider 200 is in the extreme right hand position and when the suction pressure decreases to 14 lbs., the slider 200 is in the extreme left hand position.

The relay 153 is also controlled by a balancing potentiometer formed by a slider 203 and a resistance element 204, the slider 203 being operatively connected to the motor shaft 144. As the motor 145 operates the dampers from a closed position to an open position, the slider 203 is moved from an extreme right position to an extreme left position.

The left end of the relay coil 154 is connected by wires 206, 207, 208, and 209 to the left ends of the resistance elements 181, 192, 201, and 204 and the right end of the relay coil 155 is connected by wires 210, 211, 212 and 213 to the right ends of the resistance elements 181, 192, 201, and 204. By reason of these wiring connections it is seen that resistance elements 181, 192, 201, and 204 are connected in parallel with the series connected coils 154 and 155. The junction of the relay coils 154 and 155 is connected by wires 214, 215, and 216 to the center tap of the center tapped resistance element 183, by wire 217, variable resistance 218 and wire 219 to the slider 191, by wire 220, variable resistance 221 and wire 222 to the slider 200 and by wire 223, variable resistance 224 and wire 225 to the slider 203. Accordingly all of the various potentiometers are connected in parallel with respect to each other and with the series connected relay coils 154 and 155.

Omitting for the time being the controlling action of the temperature responsive controller 185 and the pressure responsive controller 195 let it be assumed that the pressure on the high pressure side of the refrigerating apparatus is 117½ lbs. and that the dampers 140 are in the mid-position shown in the drawings. As the pressure on the high pressure side of the refrigerating apparatus increases the slider 180 is moved towards the right to decrease the energization of the relay coil 155 and increase the energization of relay coil 154 whereupon the switch arm 157 is moved into engagement with the contact 158 to move the dampers 140 towards an open position. Movement of the dampers 140 towards an open position causes left hand movement of the slider 203 which decreases the energization of the relay coil 154 and increases the energization of the relay coil 155. When the slider 203 has moved sufficiently far to the left to rebalance the energization of the relay coils 154 and 155 the dampers 140 are maintained in their newly adjusted position. Likewise, upon a decrease in pressure on the high pressure side of the refrigerating apparatus the slider 180 moves to the left to decrease the energization of the relay coil 154 and increase the energization of the relay coil 155 whereupon the switch arm 157 is moved into engagement with the contact 159 to move the dampers 140 towards a closed position. Movement of the dampers 140 towards a closed position causes right-hand movement of the slider 203 which decreases the energization of the relay coil 155 and increases the energization of the relay coil 154. When the slider 203 has moved sufficiently towards the right to rebalance the energizations of the relay coils 154 and 155 the motor 145 is stopped to maintain the dampers 140 in their newly adjusted position. Accordingly the dampers 140 are positioned in accordance with variations in pressure on the high pressure side of the

refrigerating apparatus to maintain the pressure within desired limits.

The resistance 224 associated with the slider 203 is so adjusted that complete movement of the slider 203 across its resistance element 204 is required to rebalance the action of movement of the slider 180 throughout only a portion of the total resistance 181, illustratively, a movement corresponding to a 10 lb. change in head pressure. In other words, with the slider 180 in the position shown in Figure 2 the dampers 140 are in a mid position this occurring at 117½ lbs. pressure. As the pressure decreases to 112½ lbs. the dampers 140 are moved to a completely closed position and as the pressure increases to 122½ lbs. the dampers 140 are moved to a completely open position. Accordingly a 10 lb. change in pressure on the high pressure side of the refrigerating apparatus is all that is required to cause complete opening and closing movement of the dampers 140. Since the dampers 140 control the volume of air passing through the evaporative condenser 17, they control the cooling effect of the evaporative condenser, and since the cooling effect of the evaporative condenser determines the temperature in the condenser and hence the pressure on the high pressure side of the refrigerating apparatus, the pressure responsive controller 175 therefore maintains the pressure on the high pressure side of the refrigerating apparatus within a desired range, illustratively 10 lbs.

Assume now that the temperature of the air entering the evaporating condenser is 85°, the slider 191 is therefore in the mid position as shown. The slider 191 therefore has no effect upon the energization of the relay coils 154 and 155 and accordingly the control range of the pressure controller 175 is maintained between 112½ and 122½ lbs. The compensating potentiometer formed by the slider 191 and the resistance element 192 acts to shift the control range of the control potentiometer of the pressure responsive controller 175. As the temperature decreases, the slider 191 moves towards the right to shift the 10 lb. control range of the control potentiometer towards the left, and as the temperature increases to move the slider 191 towards the left, the 10 lb. control range of the pressure controller 175 is shifted toward the right, this being made possible by the resistance element 218 which is of a relatively low resistance value. Accordingly, for variations in temperature of the air entering the evaporative condenser 17 the range of pressures on the high pressure side of the refrigerating apparatus are shifted as follows:

Temperature	Pressure
	Pounds
100°.....	140-150
85°.....	112½-122½
70°.....	85-95

Summing up as the temperature of the air increases the range of pressures maintained on the high pressure side of the refrigerating apparatus is raised and as the temperature decreases the range of pressures is lowered.

The pressure value of the suction pressure is an indication of the load on the compressor resulting from changes in the cooling load. An increase in suction pressure indicates an increase in cooling load on the compressor and a decrease in suction pressure indicates a decrease in cooling load on the compressor. A change in suction pressure also has a marked effect on the

operation of an evaporative condenser. In a refrigerating apparatus where the suction pressure varies widely, it is advisable to utilize the pressure controller 195 responding to changes in suction pressure for adjusting the control point of the head pressure responsive controller 175. The value of the resistance 221 located in series with the slider 200 of the suction pressure controller 195 is made relatively high so that the suction pressure controller 195 operates to shift the control point of the head pressure responsive controller 175 within the 10 lb. control range. Assume that the suction pressure is substantially 17½ lbs. and the outside temperature is substantially 85°, then the control point of the head pressure controller 175 is substantially 117½ lbs. If now the suction pressure increases to 21 lbs., the control point is lowered to substantially 112½ lbs. and when the suction pressure decreases to 14 lbs. the control point is raised to substantially 122½ lbs. This raising and lowering of the control point of the head pressure controller 175 within the control range is accomplished by the suction pressure controller 195 regardless of the position of the control range as determined by the outside temperature controller 185.

Figure 3 is a graph plotting horse power per ton of refrigeration against head pressure of the refrigerating apparatus of Figure 2 to illustrate how the control arrangement of Figure 2 at all times maintains the total horse power per ton of refrigeration at a minimum regardless of changes in outside temperature and changes in suction pressure. Curve A illustrates the horse power per ton of refrigeration required to operate the compressor against varying head pressures with a suction pressure of substantially 14 lbs. Curve B indicates the horse power per ton of refrigeration required to operate the compressor against varying head pressures with a suction pressure of substantially 21 lbs. Curve C indicates the horse power per ton of refrigeration required to drive the fan of the evaporative condenser to maintain various head pressures in the condenser when the temperature of the outdoor air is 85° and the suction pressure is 14 lbs. Curve D indicates the horse power per ton of refrigeration required to drive the fan of the evaporative condenser to maintain various head pressures in the condenser when the temperature of the outdoor air is 85° and the suction pressure is substantially 21 lbs. By adding the curves A and C, the total horse power per ton of refrigeration required to operate the compressor and the fan of the evaporative condenser when the outdoor temperature is 85° and the suction pressure is 14 lbs. is indicated at curve E. If under these conditions the head pressure of the refrigerating apparatus is maintained at substantially 122½ lbs. as indicated by the low point G on the curve E, the least amount of horse power per ton of refrigeration is required to operate the compressor and the fan and therefore the system will be operated most efficiently at this value of head pressure. This is exactly what is accomplished by the above outlined control system.

By adding the curves B and D, the total horse power per ton of refrigeration required to operate the compressor and the fan of the evaporative condenser is indicated by the curve F when the outdoor temperature is 85° and the suction pressure is 21 lbs. It is here noted that the low point H of the curve F occurs at a head pressure of substantially 112½ lbs. and there-

fore it is most economical to control the evaporative condenser to maintain a head pressure of substantially 112½ lbs. under these conditions and as will be readily apparent this is what the control system outlined above accomplishes.

Curve I illustrates the horse power per ton of refrigeration required to operate the fan of the evaporative condenser when the outside temperature is substantially 70° and the suction pressure is 14 lbs., and curve J illustrates the horse power per ton of refrigeration required to operate the fan when the outdoor temperature is 70° and the suction pressure is 21 lbs. By adding curve I and curve A, the total horse power per ton of refrigeration required to operate the compressor and the fan when the outdoor temperature is 70° and the suction pressure is 14 lbs. is indicated by the curve K. The curve L indicates the total horse power per ton of refrigeration required to operate the compressor and the fan when the outside temperature is 70° and the suction pressure is 21 lbs. The low point M on the curve K occurs at substantially 95 lbs. and therefore it is most economical to operate the evaporative condenser to maintain a head pressure of 95 lbs. when the outside temperature is 70° and the suction pressure is 14 lbs. Likewise, the low point N on the curve L indicates that it is most economical to operate the evaporative condenser in a manner to maintain a head pressure of substantially 85 lbs. when the outside temperature is 70° and the suction pressure is 21 lbs. Accordingly, when the outside temperature is 70°, the head pressure is caused to be varied by the above outlined control system from 85 lbs. to 95 lbs. as the suction pressure decreases from 21 lbs. to 14 lbs. to give the most efficient operation.

Curve O illustrates the horse power per ton of refrigeration required to operate the fan of the evaporative condenser when the outdoor temperature is 100° and the suction pressure is 14 lbs., and curve P illustrates the horse power per ton of refrigeration required to operate the fan when the outside temperature is 100° and the suction pressure is 21 lbs. By adding curves O and A, curve Q is obtained which indicates the total horse power per ton of refrigeration required to operate the compressor and the fan of the evaporative condenser against varying head pressures when the outside temperature is 100° and the suction pressure is 14 lbs. By adding curves P and B, curve R is obtained which represents the total horse power per ton of refrigeration required to operate the compressor and the fan against varying head pressures when the outside temperature is 100° and the suction pressure is 21 lbs. Low point S on the curve Q indicates that it is most economical to operate the evaporative condenser to maintain a head pressure of substantially 150 lbs. when the outside temperature is 100° and the suction pressure is 14 lbs., and the low point T of curve R indicates that it is most economical to operate the evaporative condenser to maintain a head pressure of substantially 140 lbs. when the outside temperature is 100° and the suction pressure is 21 lbs.

By reason of the above outlined control system of Figure 2 and by reason of the graphic showing of Figure 3, it is seen that the control system of Figure 2 operates to control the operation of the evaporative condenser to maintain the total horse power per ton of refrigeration at a minimum at all times regardless of changes in outside temperature and changes in suction

pressure. If it be desired to maintain the total horse power at a minimum at all times instead of the total horse power per ton of refrigeration, all that is necessary is to plot curves of total horse power against head pressure in a manner similar to that of Figure 3 and change the limits of the control system of Figure 2 in accordance with the data obtained from such curves. In other words, by changing the limits of the various controllers of Figure 2, it is possible to alter the system of Figure 2 to maintain the total horse power at a minimum at all times. This would be particularly applicable where the cost of electrical power is charged on a demand basis.

The proportioning motor 145 which controls the operation of the dampers 140 may also be utilized for shutting off the fan 27 and the circulating pump 23 when the dampers 140 are moved substantially to a closed position since at this time the circulation of air and water is not needed. In order to carry this out the shaft 144 of the motor 145 is provided with a cam 230 for operating a cam follower 231 which in turn operates a mercury switch 232 and is also provided with a cam 233 for operating a cam follower 234 for in turn operating a mercury switch 235.

A circuit for the circulating pump 33 is completed from the line wire 161 through wire 237, mercury switch 232, wire 238, circulating pump 233 and wire 239 back to the other line wire 162. Accordingly, when the mercury switch 232 is closed the water circulating pump 233 is in operation. The cam 230 is so arranged that when the dampers are moved to almost a closed position the switch 232 is opened to stop operation of the circulating pump 33.

The fan motor 28 is controlled by a circuit leading from the line wire 161 through wire 240, mercury switch 235, wire 241, fan motor 28, and wire 242 back to the other line wire 162. Accordingly, when the switch 235 is closed the fan motor 28 and hence the fan 27 are maintained in operation. When the dampers 140 are moved to a substantially closed position, the mercury switch 235 is opened to stop operation of the fan 27. It is thus seen that as the dampers 140 are moved towards a closed position the water circulating pump 33 is first shut off and then the fan 27 is shut off when the dampers 140 assume an extreme closed position. This results in a further saving inasmuch as it is not necessary to have the circulating pump 33 and the fan 27 operating when the dampers 140 are in a closed position.

From the above it is seen that I have provided a control system for an evaporative condenser of a refrigerating apparatus wherein the total horse power or the total horse power per ton of refrigeration required to operate the compressor of the refrigerating apparatus and the fan of the evaporative condenser is maintained at a minimum at all times regardless of changes in outside temperature and changes in suction pressure, wherein sufficiently high head pressures are maintained to insure circulation of refrigerant through the refrigerating apparatus and wherein needless operation of the evaporative condenser is prevented.

While in Figure 2 damper means 140 are shown for purposes of illustration for controlling the rate of air flow through the evaporative condenser 17, this may be equally as well accomplished by changing the speed of the fan 27 and such is within the contemplation of this invention. It is to be understood that the various

pressure and temperature values utilized in setting forth this invention are utilized for purposes of illustration only and that they may be varied to suit operating conditions of various installations.

Although for purposes of illustration two modifications of this invention have been disclosed, other forms thereof may become apparent to those skilled in the art upon reference to this disclosure and therefore this invention is to be limited only by the scope of the appended claims and prior art.

I claim as my invention:

1. In a refrigerating apparatus having evaporator means for cooling a medium, means for circulating refrigerant through the evaporator means and a condenser for condensing the refrigerant, the combination of, cooling means including water circulating means, air circulating means and means for contacting the air and water to provide evaporative cooling of the condenser, control means responsive to the pressure on the high pressure side of the refrigerating apparatus, control means responsive to the condition of the air before it contacts the water, control means responsive to the pressure on the low pressure side of the refrigerating apparatus and means controlled by the conjoint action of all of the control means for controlling the cooling effect of the cooling means.

2. In a refrigerating apparatus having evaporator means for cooling a medium, means for circulating refrigerant through the evaporator means and a condenser for condensing the refrigerant, the combination of, cooling means including water circulating means, air circulating means and means for contacting the air and water to provide evaporative cooling of the condenser, control means responsive to the pressure on the high pressure side of the refrigerating apparatus, control means responsive to the condition of the air before it contacts the water, control means responsive to the pressure on the low pressure side of the refrigerating apparatus and means controlled by the conjoint action of all of the control means for controlling the circulation of the air and hence the cooling effect of the cooling means.

3. In a refrigerating apparatus having evaporator means for cooling a medium, means for circulating refrigerant through the evaporator means and a condenser for condensing the refrigerant, the combination of, cooling means including water circulating means, power driven air circulating means and means for contacting the air and water to provide evaporative cooling of the condenser, means responsive to pressure on the high pressure side of the refrigerating apparatus for controlling the circulation of air to maintain the pressure on the high pressure side of the refrigerating apparatus within a desired range, and means responsive to the temperature of the air and cooperating with said pressure responsive means for also controlling the circulation of air to raise the range of pressures maintained on the high pressure side of the refrigerating apparatus as the temperature of the air increases.

4. In a refrigerating apparatus having evaporator means for cooling a medium, means for circulating refrigerant through the evaporator means and a condenser for condensing the refrigerant, the combination of, cooling means including water circulating means, power driven air circulating means and means for contacting

cause the pressure on the high pressure side of the refrigerating apparatus to approach the lower limit of the desired range as the pressure on the low pressure side of the refrigerating apparatus increases.

8. In a refrigerating apparatus having evaporator means for cooling a medium, means for circulating refrigerant through the evaporator means and a condenser for condensing the refrigerant, the combination of, cooling means including water circulating means, air circulating means and means for contacting the air and water to provide evaporative cooling of the condenser, means for controlling the operation of the refrigerant circulating means including means responsive to the pressure on the high pressure side of the refrigerating apparatus for preventing starting of the refrigerant circulating means until the pressure on the high pressure side of the refrigerating apparatus decreases to a predetermined value, and means responsive to the pressure on the high pressure side of the refrigerating apparatus for rendering the cooling means substantially ineffective when the pressure on the high pressure side of the refrigerating apparatus decreases to said predetermined value.

9. In a refrigerating apparatus having evaporator means for cooling a medium, means for circulating refrigerant through the evaporator means and a condenser for condensing the refrigerant, the combination of, cooling means including water circulating means, air circulating means and means for contacting the air and water to provide evaporative cooling of the condenser, means for controlling the operation of the refrigerant circulating means including means responsive to the pressure on the high pressure side of the refrigerating apparatus for preventing starting of the refrigerant circulating means until the pressure on the high pressure side of the refrigerating apparatus decreases to a predetermined value, and means responsive to the pressure on the high pressure side of the refrigerating apparatus for interrupting circulation of air when the pressure on the high pressure side of the refrigerating apparatus decreases to said predetermined value.

10. In a refrigerating apparatus having evaporator means for cooling a medium, means for circulating refrigerant through the evaporator means and a condenser for condensing the refrigerant, the combination of, cooling means including water circulating means, air circulating means and means for contacting the air and water to provide evaporative cooling of the condenser, means for controlling the operation of the refrigerant circulating means including means responsive to the pressure on the high pressure side of the refrigerating apparatus for preventing starting of the refrigerant circulating means until the pressure on the high pressure side of the refrigerating apparatus decreases to a predetermined value, and means responsive to the pressure on the high pressure side of the refrigerating apparatus for interrupting circulation of water when the pressure on the high pressure side of the refrigerating apparatus decreases to said predetermined value.

11. In a refrigerating apparatus having evaporator means for cooling a medium, means for circulating refrigerant through the evaporator means and a condenser for condensing the refrigerant, the combination of, cooling means including water circulating means, air circulating means and means for contacting the air and

water to provide evaporative cooling of the condenser, means for controlling the operation of the refrigerant circulating means including means responsive to the pressure on the high pressure side of the refrigerating apparatus for preventing starting of the refrigerant circulating means until the pressure on the high pressure side of the refrigerating apparatus decreases to a predetermined value, and means responsive to the pressure on the high pressure side of the refrigerating apparatus for interrupting circulation of air and water when the pressure on the high pressure side of the refrigerating apparatus decreases to said predetermined value.

12. In a refrigerating apparatus having evaporator means for cooling a medium, means for circulating refrigerant through the evaporator

means and a water cooled condenser for condensing the refrigerant, the combination of, means for controlling the operation of the refrigerant circulating means including means responsive to the pressure on the high pressure side of the refrigerating apparatus for preventing starting of the refrigerant circulating means until the pressure on the high pressure side of the refrigerating apparatus decreases to a predetermined value, and means responsive to the pressure on the high pressure side of the refrigerating apparatus for decreasing the supply of water to the water cooled condenser when the pressure on the high pressure side of the refrigerating apparatus decreases to said predetermined value.

ALWIN B. NEWTON.