Oct. 17, 1961 D. M. DART ET AL 3,004,402

PRESSURE RESPONSIVE CONTROL APPARATUS FOR REGULATING REFRIGERATION EQUIPMENT

Filed March 28, 1960 2 Sheets-Sheet 1

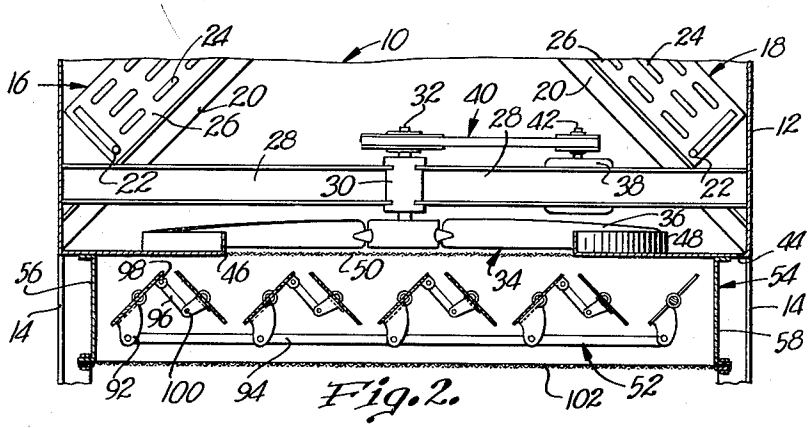


Fig. 2.

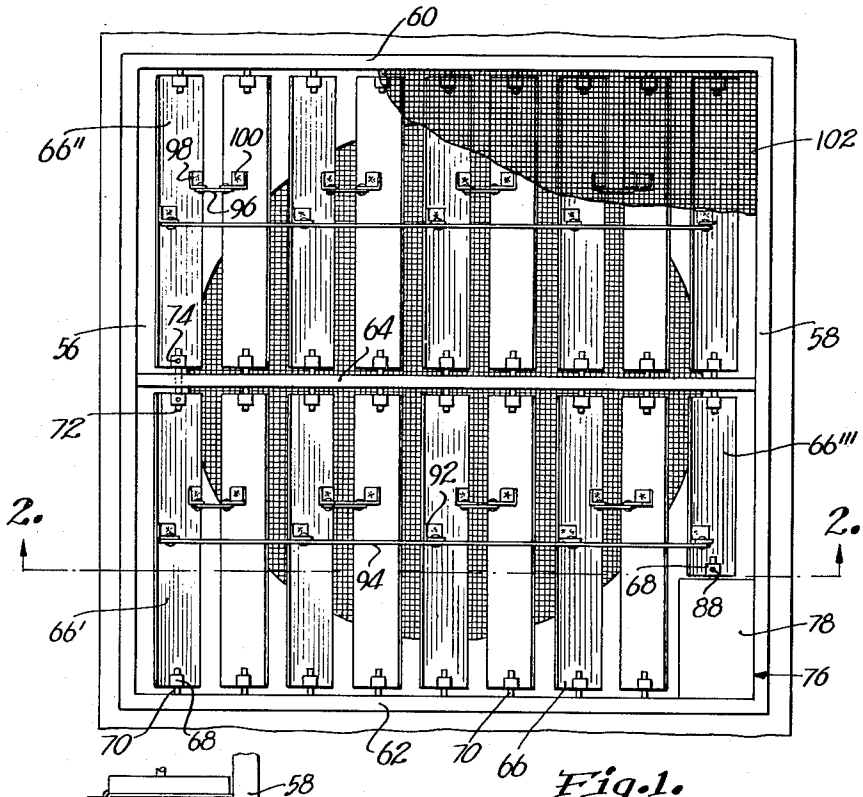


Fig. 1.

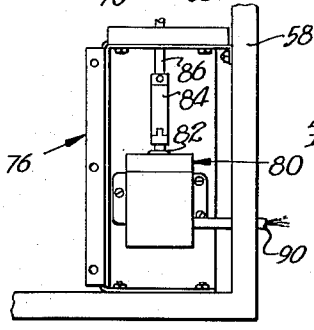


Fig. 3.

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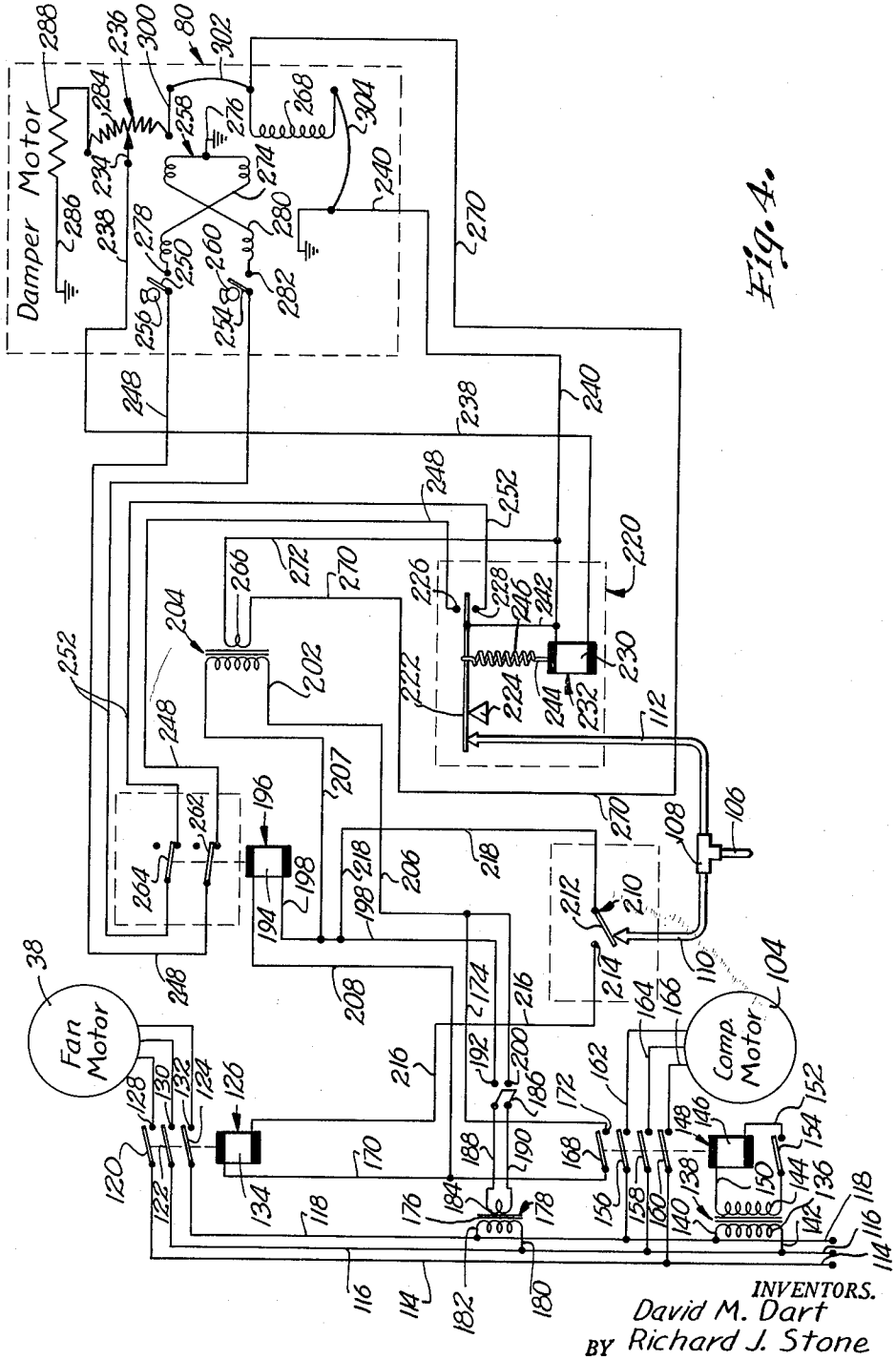


Fig. 4.

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PRESSURE RESPONSIVE CONTROL APPARATUS FOR REGULATING REFRIGERATION EQUIPMENT

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14 Claims. (Cl. 62—183)

This invention relates to heat exchange equipment and has particular application to liquid refrigerant apparatus employing an evaporator, refrigerant condensing means, a compressor and expansion valve means located between the evaporator and the condenser.

Conventional refrigeration systems having the basic components defined above, normally utilize an air cooled refrigerant condenser which is sized to handle maximum design heat loads while operating at summer dry bulb temperatures. Thus, when the ambient air temperature falls to a low level, the condensing temperature of the refrigerant and its related pressure are reduced correspondingly. During cold weather operation and also during mild weather operation with light loads, the pressure of the liquid refrigerant falls to a point where the evaporator capacity is drastically reduced because of lack of available pressure across the expansion valve. For this reason, it has been found necessary to equip an air cooled condenser with some means of control to maintain the pressure of the liquid refrigerant at a high level during periods of cold weather operation.

Although the refrigerant pressure may be controlled by a number of different ways, the primary object of this invention is to provide a cold weather control system permitting variation of the amount of air flowing across the condenser coils and thereby effecting maintenance of the refrigerant pressure at substantially a predetermined point.

Another significant object of the instant invention is to provide a control system for maintaining refrigerant pressure at a predetermined value by utilization of dampers which are movable to an infinite number of positions regulating the flow of air across the condenser coils, and with movement of the dampers being responsive to change in pressure of the refrigerant at the exit line of the compressor unit.

It is contemplated that the refrigeration system herein described employ fan means for forcing air across the condenser unit when natural convection of air across the condenser coils is insufficient to condense all of the refrigerant. It is, therefore, another important object of the invention to provide control apparatus operably coupled to the adjustable dampers as well as the fan means referred to above, to prevent the fan from cycling on and off at frequent intervals, and with the position of the dampers being adjusted so as to maintain the head pressure of the refrigerant at the selected value, and the fan being turned on only in the event that variation in the position of the dampers to change the amount of air flowing over the condenser coils is incapable of maintaining the refrigerant at the required pressure level. An important advantage of the present apparatus is therefore, the provision of means for permitting an initial operation sequence where the required head pressure of the refrigerant will be maintained by movement of the dampers only with the fan deactivated, but if the pressure of the refrigerant continues to rise above a pre-established level notwithstanding change in position of the dampers, then the fan will start automatically and remain running over a wide pressure differential so that the fan will not cycle off during the time the dampers are being moved in an effort to maintain the refrigerant pressure at the established point. This function increases the longevity of the fan unit and provides more uniform performance.

A further important object is to provide control apparatus as described including mechanism for deactivating the fan motor if the same is operating any time the compressor ceases operation. In this manner, the fan will not be started during the next cycle of the compressor until after the system has ascertained that the refrigerant pressure cannot be maintained without flow of additional air across the condenser means by activation of the fan.

Also an important aim of the invention is to provide control apparatus for refrigeration equipment having means responsive to the pressure of the refrigerant in the system for maintaining the head pressure of such refrigerant at the condenser means within a very narrow, preselected range. In order to accomplish the result desired, at least two pressure responsive controls are employed with one of the same being operably coupled to the fan for activating the latter whenever the pressure of the refrigerant increases to a pre-established value. This pressure limit control is preferably provided with a second setting arranged to maintain the fan in an activated condition until a pre-established low pressure limit is reached, at which time the control causes the fan to be stopped. Thus, any time the pressure of the refrigerant falls to a pre-established low limit, the fan will discontinue operation.

The second control operably coupled to an electric motor for operating the dampers, is also responsive to refrigerant pressure and is designed to maintain a constant, pre-established head pressure on the refrigerant by effecting movement of the dampers in response to actuation of the damper motor in either of the directions of movement thereof. The second control operates independently of the first fan limit control and serves to modulate the position of the dampers and thereby close the same to reduce air flow over the condenser unit whenever the head pressure of the refrigerant is low, or in the alternative, to effect opening of the dampers and increase air flow when the pressure of the refrigerant is high.

A still further important object of the invention is to provide control apparatus for refrigeration equipment of the type defined above wherein a switch is opened each time the compressor cycles off to preclude energization of the damper operator motor and thereby maintain the dampers at the exact position of the same at the time of stopping of the compressor. This control feature minimizes damper hunting on each cycle of operation of the compressor.

A further important object of the invention is to provide control apparatus adapted to be utilized in refrigeration equipment having a plurality of refrigerant condenser modules connected to separate compressors and including common fan means for driving air across all of the condenser modules as well as single damper structure for regulating the air flow through the unit. In this type of installation the control apparatus is operably coupled to the fan motor, the damper control motor and only one of the compressor motors. The switch mentioned in the paragraph above performs the very useful and valuable function of permitting the dampers to remain in the position that was satisfactory to maintain the desired head pressure at the exit line of the condenser modules coupled to the compressor connected in the control circuit. Thus, if the dampers are in specific position, it has been found that the head pressure is maintained without damper motion provided the load stays essentially constant. This condition of constant load is common for appreciable periods of time. The above feature makes it possible to operate a single air-cooled condenser that has multiple circuits and is used as the heat rejection means for more

than one compressor. The multiple compressor arrangement frequently used on the described systems will continue to operate satisfactorily even though the single machine operating the dampers has shut down, because the switch which de-energizes the damper motor has left the damper in a position that was satisfactory and therefore, the additional machines on the same air-cooled condenser operate as though no change had taken place. The importance of this feature is very great since it offers the possibility of using a single air cooled condenser with multiple circuits on multiple compressors for applications such as encountered in supermarkets and yet each of the machines operates as satisfactorily as the machine actually controlling the damper position. To make this possible, the fan must operate either continuously, if there are a great many compressors and almost always one would be on, or parallel contacts from each of the various compressor starters can be arranged so that the fan will start whenever any compressor comes on. The advantages inherent in the dampers remaining in a fixed position during the down-time on the control compressor is very significant and enlarges the field of application for the present control apparatus.

An additional important object is to provide control apparatus as described, wherein is included a relay for reactivating the damper control motor whenever the controlling compressor shuts down, thus making it possible to operate a group of condensers on separate circuits in a single air cooled condenser with all of the compressors being controlled indirectly by the damper position required by the control compressor.

Another significant aim of the instant invention is to provide control apparatus for a refrigeration unit wherein means for controlling energization of the damper operator motor preferably comprises a proportioning control capable of causing the damper motor to seek a position and remain essentially fixed for any given set of operating conditions. Thus, in operation of the refrigeration unit, the dampers do not constantly open and close as in prior apparatus of this general type but instead, seek a position to maintain the pressure of the refrigerant at a predetermined value. The proportioning control is of the type preventing the dampers from oscillating excessively during operation of the unit regardless of the direction in which such dampers are being moved in order to provide more or less air to compensate for a change in the pressure of the liquid refrigerant in the refrigeration system.

Also an object of the invention is to provide control apparatus of the characteristics described wherein the field windings of the damper operator motor are maintained in an energized condition regardless of the condition of energization of the clockwise and counterclockwise armature windings of such motor, this construction being significant since it is desirable that the motor be immersed in an oil bath and maintenance of the field windings in an energized condition prevents the oil from increasing in viscosity in cold weather to an extent which would interfere with movement of the dampers to positions regulating the air flow over the condenser means.

Other important objects and details of construction and operation of the instant control apparatus will become obvious or be explained in greater detail as the following specification progresses.

In the drawings:

FIGURE 1 is a bottom view looking upwardly, of refrigeration equipment as contemplated by the present invention and showing the housing for the condenser means as well as the dampers controlling movement of air into the housing and across the condenser, with certain parts of the damper structure being broken away to reveal details of construction of the components thereabove;

FIG. 2 is a fragmentary, vertical cross-sectional view taken on the line 2—2 of FIG. 1 and looking upwardly in the direction of the arrows;

FIG. 3 is an enlarged, fragmentary, bottom view of the damper operator motor showing the way in which the same is operably coupled to one of the dampers; and

FIG. 4 is a schematic wiring diagram of the present control apparatus and illustrating the various electrical and mechanical components thereof.

In refrigeration systems utilizing an air cooled condenser, such condenser is generally constructed of a size such that the same will have adequate capacity under the most adverse operating conditions likely to be encountered. These adverse conditions occur at times of highest dry bulb temperature since this parameter directly determines the required size of the condenser. Therefore, assuming that this would mean a condenser unit was constructed in a manner so that when the ambient temperature was at 100° F., the condensing temperature of the refrigerant would be approximately 120° F., the condenser would be sized so that the condensing temperature differential would be 20° F. Inasmuch as refrigeration compressors are limited in the maximum condensing temperature they can handle, the 120° F. is basically a limit and thereby determined by the compressor manufacturer. These two factors, compressor limits and maximum condensing temperature, are used only as design conditions for construction of the equipment, but it is apparent that these conditions will occur only a very small percentage of the time, with the temperature being less than that specified the largest proportion of the time, while during only a small percentage of the operating time of the equipment will the ambient temperature be above that indicated. Therefore, for the largest percentage of time of operation of the unit, the refrigeration equipment will operate at a lower temperature than 100° F. Since the condenser unit is sized for a 20° F. temperature differential, the result will be a decrease in the condensing temperature in response to lowering of the ambient dry bulb temperature. This, of course, assumes that the load on the evaporator remains approximately constant and although this is not the case in certain instances, in commercial operations where food storage is involved for example, the load on the evaporator does remain essentially constant regardless of the season. Furthermore, many modern buildings are rather completely enclosed and depend on cooling and air conditioning the year around and where the number of people or sun effects are appreciable, these buildings need cooling even though the outdoor temperature is low. For purposes of the present control system, it may therefore be assumed that the load on the evaporator is substantially constant.

Food storage and cooling of buildings are only two examples of why a refrigeration system must be designed so as to be operable the year around and at low ambient temperatures during winter months. A problem is presented, therefore, because as the condensing temperature decreases, the condensing pressure also decreases. The required evaporator temperature and pressure remain basically constant, however, because of the rather constant load on the evaporator as discussed above. This means that the temperature and pressure difference between condensing and evaporating is decreased as the outdoor ambient temperature is reduced and therefore, reducing the pressure differential of the refrigerant and resulting in inadequate pressure on the liquid as the same flows through the expansion valve of the refrigeration system. It can be recognized that as the pressure differences are reduced and particularly the pressure of the refrigerant at the expansion valve, the flow therethrough becomes inadequate to maintain the required cooling effect and the refrigeration system loses a substantial proportion of its evaporating capacity. It has been observed that in very cold weather the refrigeration capacity of the evaporator can be reduced to a level very close to zero.

Although systems have previously been devised to introduce some of the cold ambient air into the area being

cooled, it has been found extremely complicated to control the introduction of such cold air into the area in which the evaporator is disposed and this additional equipment is more expensive than a conventional refrigeration system which is used the year around. It is therefore apparent that a need existed to operate the refrigeration systems the year around regardless of the ambient temperature conditions and with the evaporating capacity of the unit remaining substantially constant. The present control system for refrigeration equipment is designed to overcome the above problems.

Refrigeration equipment broadly designated by the numeral **10** and embodying the preferred components and concepts of the instant invention, includes an open top and bottom, generally rectangular, metallic housing **12** supported on a number of vertical, horizontally spaced, transversely angularly shaped legs **14** which are preferably placed at least at respective corners of housing **12**.

In the preferred refrigeration unit as illustrated, a pair of condenser banks **16** and **18** are mounted within housing **12** on respective angularly disposed supports **20** which converge as the uppermost extremities thereof are approached so that banks **16** and **18** are in substantially V-shaped configuration, as illustrated in FIG. 2. The details of construction of banks **16** and **18** are not illustrated or believed pertinent to the instant invention, but it is pointed out that each of the same includes an inlet line and an outlet pipe **22** which communicate with serpentine conduits **24** carried by a large number of transversely extending, longitudinally aligned, horizontally spaced fins **26**.

A number of channel members **28** mounted in the lowermost end of housing **12** and extending in diagonal fashion, support upright bearing **30** at the zone of juncture of respective channels **28**, with a shaft **32** being rotatably carried by bearing **30** and disposed in a vertical position. Fan blade means **34** secured to the lowermost end of shaft **32** below channels **28** include a number of blades **36** having a pitch to force air upwardly through the lower open end of housing **12** in response to rotation of shaft **32** by electric motor **38** through belt and pulley means **40** operably coupling shaft **42** of motor **38** to shaft **32**.

A horizontal plate **44** secured to the lowermost rectangular margin of housing **12** has a centrally disposed, circular opening **46** therein coaxial with shaft **32** and thereby fan means **34**, while an upstanding, circular flange **48** is secured to the upper face of plate **44** in circumscribing, complemental relationship to opening **46**. In order to preclude passage of objects into the interior of housing **12** through opening **46** which might bend or otherwise injure fins **26** of condenser banks **16** and **18**, a circular screen **50** is carried by plate **44** in covering relationship to opening **46**.

Damper means broadly designated **52** and designed to regulate flow of air upwardly through housing **12** either by natural convection or during operation of fan means **34**, comprises a rectangular frame **54** open at the top and bottom thereof, secured to the underface of plate **44**, depending therefrom and coaxial with shaft **32**.

Frame **54** includes a pair of side, channel-shaped elements **56** and **58** as well as channel-shaped end elements **60** and **62**. Cross member **64** spans the distance between side elements **56** and **58** is and disposed midway between end elements **60** and **62**.

A number of elongated damper blades **66** are carried by frame **54** therewithin, with each of the blades **66** having a centrally disposed bearing **68** at opposed ends thereof and adapted to pivotally receive corresponding pivot pins **70** secured to the inner faces of end elements **60** and **62** as well as opposed surfaces of cross member **64**. The only exception to this is shaft **72** extending through the bearings **68** on blade units **66'** and **66''** adjacent side element **56**, it being noted in FIG. 1 that shaft **72** is secured to corresponding bearings **68** by set-

screws **74** so that upon rotation of damper blade **66'**, blade **66''** is rotated therewith a corresponding distance.

It should also be noted that blade **66'''** adacent side element **58** and end element **62** respectively, is substantially shorter than the remaining damper blades to compensate for motor housing **76** disposed within frame **54** at the corner of side element **58** and end element **62**.

As best shown in FIG. 3, wherein the cover plate **78** of housing **76** is removed, damper operator motor **80** positioned within housing **76** has an output shaft **82** directly aligned with the axis of rotation of blade **66'''**. Coupling **84** connects output shaft **82** to shaft **86** which is secured to the proximal bearing **68** on blade **66'''** by setscrew **88**. Electrical conduit **90** extending from motor **80** through side element **58** carries power lines for permitting selective actuation of motor **82** in a manner to be defined in greater detail hereinafter.

Damper blades **66'** and **66''**, as well as every alternate blade **66** including blade **66'''**, have a generally L-shaped depending bracket **92** secured to the normally undermost surfaces thereof intermediate the ends of such blades and in alignment perpendicularly of corresponding blades **66**, as best shown in FIG. 1. Links **94** are pivotally secured to and interconnect the lowermost extremities of brackets **92** with links **94**, thereby being in parallel relationship as indicated in FIG. 1. Alternate pairs commencing with blade element **66'** and **66''** are also interconnected by short links **96** coupled to brackets **98** and **100** respectively, secured to the underside of respective blade units **66**. The disposition and location of links **96** as well as brackets **98** and **100** interconnecting alternate pairs of blade units **66** is best illustrated in FIG. 1.

Another screen **102**, which is rectangular in configuration, is placed in underlying relationship to frame **54** in closing relationship to the opening therein to also prevent entrance of foreign objects into the interior of housing **12**, and it is also contemplated that screens be provided at the uppermost end of housing **12** to preclude gravitational entrance of foreign materials into the interior of unit **10**.

In the schematic wiring diagram shown in FIG. 4, the compressor motor forming a part of the refrigeration unit is designated by the numeral **104**, while a refrigerant conduit **106** communicating with pipes **22** has a T **108** therein coupling line **106** to lines **110** and **112** respectively. Inasmuch as it is assumed that fan motor **38** and compressor motor **104** are of the three phase, alternating current type, the three power lines therefor are designated **114**, **116** and **118**. The switch arms **120**, **122** and **124** of relay **126** are interposed in lines **114**, **116** and **118** respectively, with arms **120**, **122** and **124** being engageable with corresponding contacts **128**, **130** and **132**. The coil **134** of relay **126** is interposed in a circuit to be hereinafter described.

The primary windings **136** of transformer **138** are connected to lines **116** and **118** by lines **140** and **142** respectively, while the secondary windings **144** of transformer **138** are connected to the coil **146** of relay **148** by respective lines **150** and **152**. It is to be noted that a switch **154** is interposed in line **152** and which is operated by compressor motor **104** in a manner to cause switch **154** to be closed during operation of motor **104** and in an open condition during deactivation of such motor.

Switch arms **156**, **158** and **160** of relay **148** are interposed in conduits **162**, **164** and **166** respectively, coupling lines **114**, **116** and **118** to compressor motor **104**. The other switch arm **168** of relay **148** is connected to a line **170** leading to coil **134** of relay **126**, while contact **172** of relay **148** and engaged by arm **168** is coupled to a line **174**.

The secondary windings **176** of another transformer **178** is then coupled to lines **116** and **118** by lines **180** and **182**, and the primary windings **184** of such transformer are connected to corresponding arms of a double

pole, single throw, manually operable switch 186 by lines 188 and 190. Contact 192 of switch 186 is joined to the coil 194 of relay 196 by line 198, and the other contact 200 of switch 186 is coupled to the secondary windings 202 of transformer 204 by line 206. Line 207 couples coil 202 of transformer 204 to line 198. Coil 194 of relay 196 is also joined to line 170 by line 208. An auxiliary high-low pressure switch 210 forming a part of the instant control apparatus has a switch arm 212 which is moved in response to the pressure of refrigerant in line 110. As will be made clearer hereinafter, switch arm 212 remains out of engagement with its contact 214 until the pressure in line 110 reaches a predetermined high level and by the same token, arm 212 remains in engagement with contact 214 after closing of switch 210, until the pressure of the refrigerant in line 110 recedes to a second predetermined low level. Line 216 joins contact 214 of switch 210 to the coil 134 of relay 126, and line 218 interconnects switch arm 212 and line 198.

The control apparatus also includes a proportioning control switch broadly designated 220 having a switch arm 222 pivotal about a fixed fulcrum 224 and with one end of arm 222 being movable into alternate engagement with opposed switch contacts 226 and 228. Pivoting of arm 222 about fulcrum 224 is effected by virtue of operable connection of line 212 to arm 222 to shift the latter in response to change of refrigerant pressure in line 112. The coil 230 of solenoid 232 forming a part of control switch 220, is coupled to arm 234 of a potentiometer 236 forming a part of damper operator motor 80, by a line 238. Another line 240 coupled to coil 230 serves as a ground for the latter.

It should be noted at this juncture that a flexible line 242 electrically connects switch arm 222 to ground line 240, while the armature 244 of solenoid 232 is connected to one end of a coil spring 246 which is joined at the opposite end thereof to switch arm 222 intermediate fulcrum 224 and contacts 226 and 228. The extent to which spring 246 biases arm 222 toward contact 228 is determined by the position of armature 244 relative to coil 230 of the solenoid 232.

Line 248 couples contact 226 to cam operated limit switch arm 250, while line 252 joins contact 228 to cam actuated limit switch arm 254. As will be explained hereinafter, cam 256 permits switch arm 250 to open after the armature 258 of motor 80 has rotated in one direction to the end of its path of travel, while cam 260 associated with arm 254 permits the latter to open during rotation of armature 258 in the opposite direction and after the same has reached the limit of its path of rotational movement.

Relay switch arm 262 and relay switch arm 264, forming a part of relay 196, and interposed in lines 248 and 252 respectively, are movable into closed condition in response to energization of coil 194 as hereinafter described.

The primary windings 266 of transformer 204 are connected to the field windings 268 of damper operator motor 80 by line 270 and to ground line 240 by line 272.

Damper operator motor 80 includes counterclockwise armature windings 274 connected to ground line 276 and the contact 278 adapted to be engaged by arm 250. Clockwise armature windings 280 are likewise joined to ground 276 and to contact 282 disposed to be engaged by limit switch arm 254. One end of potentiometer coil 284 is grounded by a line 286 having a resistor 288 therein, the opposite end of coil 284 being coupled to line 300. Jumper wire 302 interconnects lines 300 and 270. Another jumper wire 304 joins one end of field windings 268 to ground line 240.

In operation of refrigeration equipment 10 employing the control circuit illustrated schematically in FIG. 4, a proportioning control adjusting knob forming a part of control switch 220 (not shown) is initially set at a predetermined pressure, depending upon the refrigerant utilized. For example, with dichlorodifluoromethane the control preferably should be set at 125 p.s.i.g., while such setting should be approximately 205 p.s.i.g. if chlorodifluoromethane is employed. The high-low pressure switch 210 is also adjusted so that the same remains in an open condition until a pressure of 150 p.s.i.g., or 250 p.s.i.g. respectively for dichlorodifluoromethane and chlorodifluoromethane, is reached. Similarly, the switch is set so that the same does not open until a low pressure of 50 p.s.i.g. or 90 p.s.i.g. is reached for the corresponding refrigerants dichlorodifluoromethane and chlorodifluoromethane, as set forth above. It is to be understood that these pressures are exemplary only for the particular refrigerants and may be varied in certain circumstances to meet the ambient conditions encountered. As will be explained hereinafter, the pressure switch should be adjusted if fan motor 38 cycles on and off at frequent intervals, and the proportioning control 220 should be adjusted if the head pressure of the refrigerant is at too high a value or too low.

Next, the equipment is placed in operation by closing manually operable, double pole switch 186, it being assumed that compressor motor 104 is cycled off and on by thermostat means forming no part of the present apparatus and therefore not illustrated.

Closing of switch 186 causes coil 202 of transformer 204 to be energized from coil 176 of transformer 178 connected to lines 116 and 118 by lines 180 and 182, through coil 184 and line 188, one arm of switch 186, contact 192, line 198, line 207, coil 202, line 206, contact 200, the other arm of switch 186 and line 190.

Field windings 268 of damper motor 80 are simultaneously energized through a circuit including coil 266 of transformer 204, line 272, line 240, jumper wire 304, coil 268 and line 270. It is assumed initially that switch arm 222 is in the perfectly balanced position thereof as illustrated in FIG. 4 and thereby not engaging either of the contacts 226 and 228. Likewise, armature 258 of motor 80 is in the central disposition of the same with potentiometer 234, operable in response to rotation of armature 258, being in the central position intermediate the ends of the path of travel thereof across coil 284. However, cams 256 and 260 are in locations maintaining respective switch arms 250 and 254 in engagement with contacts 278 and 282. No current flows to armature windings 274 and 280 because switch arm 222 is in an open condition as set forth above.

Closing of switch 186 also effects energization of relay 196 through coil 184, line 188, one arm of switch 186, contact 192, line 198, coil 194, line 208, line 170, switch arm 168 in engagement with contact 172, line 174, line 206, contact 200, the other arm of switch 186 and line 190. Closing of switches 262 and 264 of relay 196 in response to energization of coil 194 permits current to pass to either of the armature windings 274 and 280 of damper motor 80 upon engagement of switch arm 222 with contact 226 or contact 228. The circuit from contact 226 to armature 258 may be traced by line 248 and including closed switch 262, switch arm 250, contact 278, armature winding 274 and ground line 276. The opposed contact 228 is coupled to armature winding 280 through line 252, including closed switch 264, switch arm 254, and contact 282 joined to winding 280 with the latter in turn also being grounded to line 276.

It is to be understood that switch 154 is closed in response to a thermostatic or pressure control forming a part of the refrigeration system and not illustrated, for sensing the point at which it is desired that compressor motor 104 be energized to operate the compressor. Closing of switch 154 causes coil 146 of relay 148 to be energized through windings 144 of transformer 138, line 150, coil 146, and line 152 including closed switch 154. Switches 156, 158 and 160 are closed in response to energization of relay coil 146 whereby current is per-

mitted to pass to compressor motor 104 from power lines 114, 116 and 118 via lines 166, 164 and 162 respectively. Means controlling switch 154 is of a nature to prevent frequent cycling of compressor motor 104 and therefore the latter will run for a substantial period of time in accordance with concepts well known in this field.

Switch arm 168 of relay 148 moves into engagement with contact 172 in response to activation of relay 148 but the coil 134 of relay 126 is not energized at this juncture unless switch 210 is closed. Since relay 126 remains deenergized so long as switch 210 is open, fan motor 38 remains in an inactive condition and fan blade means 34 are not caused to rotate.

However, when the pressure of the refrigerant in conduit 106 reaches a predetermined high level as determined by the setting of high-low switch 210, switch arm 212 moves into engagement with contact 214 whereby relay 126 is energized through a circuit including windings 184 of transformer 178, line 188, one switch arm of switch 186, contact 192, line 198, line 218, switch arm 212, contact 214, line 216, coil 134, line 170, switch arm 168, contact 172, line 174, line 206, contact 200, the other arm of switch 186 and line 190. During energization of fan motor 38, the shaft 42 thereof is turned to cause fan means 34 to be rotated by shaft 32 through belt and pulley means 40. As fan means 34 rotates, air is drawn inwardly through the lowermost end of housing 12, past the damper structure arranged below fan means 34, and thence upwardly over condenser banks 16 and 18. Screens 50 and 102 serve to preclude entrance of foreign articles into the interior of housing 12 which would damage the fins of banks 16 and 18.

Motor 38 continues to operate by virtue of the windings thereof being energized directly from power lines 114, 116 and 118, while switches 120, 122 and 124 of relay 126 remain closed, unless the pressure of the refrigerant in line 106 drops to a predetermined low level permitting switch 210 to open, thereby effecting deenergization of coil 134 or, in the alternative, upon stopping of compressor motor 104 whereby switch 154 opens and permitting switch arm 168 to move out of engagement with contacts 172 and breaking the circuit to relay 126.

The components described above are effective in preventing fan motor 38 from cycling on and off at frequent intervals and, as will be pointed out in detail, proportioning control 220 causes the dampers to hunt a position maintaining the head pressure of the refrigerant at a preselected value and while fan motor 38 continues to run, so that frequent starting and stopping of the latter is precluded.

Assuming that fan motor 38 is in operation and the head pressure of the refrigerant in line 106 falls in response to passage of additional air over condenser banks 16 and 18, switch 222 is caused to swing about the fulcrum 224 until one end of switch 222 engages contact 226. Armature winding 274 of damper operator motor 80 is thereby energized through a circuit including coil 266 of transformer 204, line 272, line 240, flexible line 242, switch arm 222, contact 226, line 248 including closed switch 262, switch arm 250, contact 278, windings 274 and ground line 276. During energization of armature windings 274, armature 258 of motor 80 is caused to be rotated in a counterclockwise direction whereby damper blades 66 are rotated toward the closed positions thereof through corresponding links 94 and 96 as well as shaft 72.

It is to be noted that as armature 258 is rotated as outlined above, potentiometer arm 234 is rotated therewith and in a direction toward resistor 288 whereby the voltage passing to coil 230 of solenoid 232 varies in response to change in position of arm 234. It is to be appreciated that closing of manually operable switch 186 effects immediate energization of coil 230 of solenoid 232 through a circuit from transformer 204 which is energized from lines 116 and 118 upon closing of the switch arms of switch 186, with coil 230 being interposed in a circuit including windings 266, line 272, line 240, the windings of solenoid 232, line 238, potentiometer arm 234, coil 284, line 300, jumper wire 302 and line 270. By virtue of the increase in voltage to coil 230 as potentiometer 234 is moved toward resistor 288, coil spring 246 exerts a greater force on switch arm 222 and pulls the latter out of engagement with contact 226 prior to the time armature 258 reaches the end of its counterclockwise path of travel and at a point where the pressure of the refrigerant is substantially at the preselected value.

A rise in head pressure of refrigerant in line 106 causes switch arm 222 to be moved into engagement with contact 228, thereby energizing armature winding 280 of damper operator motor 80 through a circuit including the coil 266 of transformer 204, line 272, line 240, flexible line 242, switch arm 222, contact 228, line 252 including closed switch 264, switch arm 254, contact 282, the windings 280 of armature 258 and ground line 276. Energization of windings 280 causes armature 258 to be rotated in a clockwise direction, thereby effecting opening of the damper means below fan means 34 and also causing potentiometer arm 234 to be moved away from resistor 288. As potentiometer arm 234 moves away from resistor 288, the voltage to coil 230 of solenoid 232 decreases, thereby permitting the inherent upward bias of switch 222 to move the latter out of engagement with contact 228 and at the point where the pressure of the refrigerant is substantially at the preselected value and again prior to rotation of armature 258 to the end of its clockwise path of travel.

Proportioning control 220 thereby precludes operator motor 80 from oscillating and the dampers hunt out the proper position to effect a balance between the condensing temperature and pressure of the refrigerant and the ambient air conditions. Although proportioning control 220 has been illustrated only schematically, the description thereof is believed to be sufficiently complete to permit practice of the instant invention, particularly with reference to a specific control, a suitable one being type PP–A, manufactured by the Barber-Colman Company, Rockford, Illinois, and described in Bulletin No. F–6452–2.

It has also been determined that a single-pole, double-throw, free-floating switch may be substituted for the proportioning control 220 if desired, and operable results are obtained even though the sensitivity of such switch is not as great as the proportioning unit 220. In substituting a free-floating switch for the proportioning control, the contacts corresponding to contacts 226 and 228 of control 220, would be coupled to the armature windings of damper motor 80 in the same manner as illustrated in FIG. 4, but the solenoid 230 and potentiometer 236 would not be used in the modified construction. In the preferred embodiment, the pressure differential on a switch arm such as 222, necessary to move the latter from one end of its path of travel, would approximate ten pounds, and with the switch arm moving out of engagement with a corresponding contact upon the slightest deviation from the specified high and low pressure values. A snap-type switch would not be required in the described construction by virtue of the low voltages involved, particularly when it is recognized that the armature windings 274 and 280 are interposed in a circuit between ground wires 240 and 276. The operation of the control apparatus embodying the free-floating switch would be essentially the same as the operation of the control apparatus embodying proportioning control 220 and, therefore, will not be described in detail.

The instant control apparatus is also of particular advantage in refrigeration equipment having a number of individual condenser modules disposed within a common housing, and each connected to a corresponding com-

pressor. Units of this type generally have common fan means for directing air through all of the condenser modules, and also would employ only a single bank of dampers for regulating flow of air through the module housing.

The control apparatus as described herein would be operably coupled to the fan motor and the damper operator motor, as well as to one of the compressor motors associated with the compressor operably coupled to a single condenser module. Under these circumstances, the damper operator motor would be actuated in response to the head pressure at the exit line of the condenser coupled to the compressor motor in circuit with the control system, and operable independently of the remaining compressors.

This construction precludes the necessity of providing individual controls on all of the compressor motors and eliminates a considerable number of components in the nature of conduits, pressure controls, headers, and similar electrical and mechanical equipment which has been employed in the past on each of the compressors of the multiple assembly. In equipment of this type, it is desirable to utilize a thermostatic switch in series with switch **210** for preventing the fan motor **38** from cycling on if the temperature is below a predetermined value. Furthermore, a second high-low pressure switch should be provided in parallel with switch **210** to cycle fan motor **389** if the pressure of the refrigerant reaches a very high level to thereby prevent high amplitude peaks in a graph of the pressure plotted against time, as would occur if each of the compressors has automatic defrosting control means thereon operable at predetermined intervals.

The relay **196** deactivates damper operator motor **80** whenever the controlling compressor motor **104** shuts down, thereby making it possible to operate a group of compressors on separate circuits in a single air-cooled condenser housing, and with control of all of the compressors being effected indirectly by the damper position required for the control compressor. The system will continue to operate satisfactorily for an extended period of time while the control compressor is shut down during a defrost cycle and without damper oscillation which would occur if damper structures of the type heretofore used were employed for each of the compressors to regulate flow of air over a corresponding condenser. The effect on the compressors other than the control compressor during a defrost cycle, would be negligible because in general, changes in ambient air conditions are relatively slow and it is extremely rare when such change would be sufficiently great to have an adverse effect on operation of the remaining compressors during defrosting of the control compressor.

It should also be noted that temperature sensitive controls can be used to actuate the damper operator for motor **80**, and maintain a constant temperature from the air cooled unit. This type of arrangement would be particularly applicable when a fluid such as water is circulated through the air cooled machine rather than a volatile refrigerant. The principles and theory of operation would be identical, except that temperature, instead of pressure, would serve as the basis of control. Operation of several independent circuits on a single air-cooled machine would likewise be possible in this arrangement because of the provision of relay switch **196**, as well as the other features of delayed fan action and preventing of excessive oscillation of the dampers.

As previously indicated, it is preferable that damper motor **80** be of the type wherein the same is submerged in an oil bath and therefore, relay **196** serves to maintain field windings **268** of motor **80** in an energized condition regardless of the condition of operation of fan motor **38** and compressor motor **104**, whereby armature **258** is movable under control of switch **220** regardless of the ambient air conditions.

Having thus described the invention what is claimed as new and desired to be secured by Letters Patent is:

1. In refrigeration equipment having condenser means, refrigerant supply and return means connected to said condenser means, power driven fan means disposed to direct air through the condenser means, and movable damper structure for controlling the amount of air permitted to pass through said condenser means by natural convection and during operation of said fan means, the improvement of which comprises apparatus for actuating said fan means and the damper structure, said apparatus including mechanism for moving the damper structure to and from the open and closed positions thereof to regulate the amount of air permitted to pass over the condenser means; control means operably connected to said mechanism for actuating the latter to move said damper structure a distance in either of the directions of movement thereof, sufficient only to control flow of air over said condenser means by natural convection or during operation of said fan means and attempt to maintain the air flow, air temperature and predetermined condensing temperature in balance; and means controlling operation of said fan means for activating and deactivating the latter only after the head pressure of said refrigerant has reached preselected high and low levels respectively, and regardless of the positions of said dampers.

2. In refrigeration equipment having condenser means, refrigerant supply and return means connected to said condenser means, power driven fan means disposed to direct air through the condenser means, and movable damper structure for controlling the amount of air permitted to pass through said condenser means by natural convection and during operation of said fan means, the improvement of which comprises apparatus for actuating said fan means and the damper structure, said apparatus including mechanism for moving the damper structure to and from the open and closed positions thereof to regulate the amount of air permitted to pass over the condenser means; control means responsive to the pressure of the refrigerant and operably connected to said mechanism for actuating the latter to move said damper structure a distance in either of the directions of movement thereof, sufficient only to control flow of air over said condenser means by natural convection or during operation of said fan means and attempt to maintain the air flow, air temperature and predetermined condensing temperature in balance; and means controlling operation of said fan means for activating and deactivating the latter only after the head pressure of said refrigerant has reached preselected high and low levels respectively, and regardless of the positions of said dampers.

3. In refrigeration equipment having condenser means, refrigerant supply and return means connected to said condenser means, power driven fan means disposed to direct air through the condenser means, and movable damper structure for controlling the amount of air permitted to pass through said condenser means by natural convection and during operation of said fan means, the improvement of which comprises apparatus for actuating said fan means and the damper structure, said apparatus including mechanism for moving the damper structure to and from the open and closed positions thereof to regulate the amount of air permitted to pass over the condenser means; control means operably connected to said mechanism for actuating the latter to move said damper structure a distance in either of the directions of movement thereof, sufficient only to control flow of air over said condenser means by natural convection or during operation of said fan means and attempt to maintain the air flow, air temperature and predetermined condensing temperature in balance; and means controlling operation of said fan means for activating the latter only after the dampers have been shifted to substantially the completely open position thereof and the resulting currents

of air passing over the condenser means by natural convection are insufficient to maintain the head pressure of the refrigerant above a predetermined value.

4. In refrigeration equipment having condenser means, compressor means, refrigerant supply and return means connected to said condenser means and said compressor means, power driven fan means disposed to direct air through the condenser means, and movable damper structure for controlling the amount of air permitted to pass through said condenser means by natural convection and during operation of said fan means, the improvement of which comprises apparatus for actuating said fan means and the damper structure, said apparatus including mechanism for moving the damper structure to and from the open and closed positions thereof to regulate the amount of air permitted to pass over the condenser means; control means responsive to the pressure of the refrigerant and operably connected to said mechanism for actuating the latter to move said damper structure a distance in either of the directions of movement thereof, sufficient only to control flow of air over said condenser means by natural convection or during operation of said fan means and attempt to maintain the air flow, air temperature and predetermined condensing temperature in balance; means controlling operation of said fan means for activating and deactivating the latter only after the head pressure of said refrigerant has reached preselected high and low levels respectively, and regardless of the positions of said dampers; and means connected to said control means for preventing movement of said dampers during periods of inactivation of the compressor means.

5. In refrigeration equipment having condenser means, refrigerant supply and return means connected to said condenser means, power driven fan means disposed to direct air through the condenser means, and movable damper structure for controlling the amount of air permitted to pass through said condenser means by natural convection and during operation of said fan means, the improvement of which comprises apparatus for actuating said fan means and the damper structure, said apparatus including an electric damper motor operably coupled to said structure for moving the dampers to and from the open and closed positions thereof to regulate the amount of air permitted to pass over the condenser means; electrically operated proportioning control means operably connected to said damper motor and responsive to head pressure of said refrigerant for actuating said damper motor to move said dampers a distance in either of the directions of movement thereof, sufficient only to control flow of air over said condenser means by natural connection or during operation of said fan means and attempt to maintain the air flow, air temperature and predetermined condensing temperature in balance; and means controlling operation of said fan means and responsive to head pressure of said refrigerant for activating or deactivating the fan means only after the head pressure of said refrigerant has reached preselected high and low levels respectively, and regardless of the position of said dampers.

6. Refrigeration equipment as set forth in claim 5, wherein said fan means includes an electrical fan motor, said apparatus having an electrical circuit coupled to said fan motor and said last-mentioned means being interposed in said circuit and comprising a contact element, a first switch arm movable into and out of engagement with said element and movable in response to change in head pressure of the refrigerant, and means for maintaining said switch arm in either the open or closed position thereof until said head pressure of the refrigerant against said switch arm reaches a predetermined high or low value.

7. Refrigeration equipment as set forth in claim 5, wherein said damper motor has field windings and a pair of armature windings for causing the armature of said damper motor to be rotated in opposite directions as corresponding armature windings are energized, said proportioning control means including a pair of opposed contact members and a second switch arm movable between engagement with said contact members, said second switch arm being shiftable in response to change in head pressure of the refrigerant, and circuit means connecting the contact members to respective armature winding and the second switch arm and said field windings to a source of power whereby the field windings remain energized regardless of the condition of energization of said armature windings.

8. Refrigeration equipment as set forth in claim 7, wherein is provided third switch means in said circuit means coupling said contact members to respective armature windings of the damper motor, said third switch means being opened each time the compressor is deactivated to thereby preclude energization of the armature windings of the damper motor in response to movement of said second switch arm into engagement with said contact members but with said field windings of the damper motor remaining in an energized condition.

9. In refrigeration equipment having a housing open at the top and bottom thereof, condenser means with said housing, compressor means, refrigerant supply and return means connected to said condenser means and the compressor means, and power driven fan means disposed within the housing to direct air through the condenser means, the improvement of which comprises movable damper structure adapted to be mounted in the housing in a position to control the amount of air permitted to pass through the condenser means by natural convection and during operation of said fan means, said damper structure including a plurality of elongated, flat blade units disposed in juxtaposed relationship and rotatable about parallel axes extending across the housing, a damper motor having a shaft and connector means coupling said shaft to the blade units for rotating alternate blade units in opposite directions; and control means operably connected to said damper motor for actuating the latter to move said blade units a distance in either of the directions of movement thereof, sufficient only to control flow of air over said condenser means by natural convection or during operation of said fan means to thereby substantially maintain the air flow, air temperature and predetermined condensing temperature in balance.

10. Refrigeration equipment as set forth in claim 9, wherein said connector means includes components coupling the shaft of the damper motor to one of the blade units for rotating the latter in response to actuation of said damper motor, link means interconnecting remaining alternate blade units to said one blade unit for rotating said remaining alternate blade units in the same direction and in response to movement of said one blade unit, and link structure coupling each of said alternate blade units to the next adjacent blade unit in one direction therefrom for rotating said next adjacent blade units in a direction opposite to that of said alternate blade units.

11. Refrigeration equipment as set forth in claim 10, wherein said link means and the link structure causes said blade units to be rotated through equal arcs in response to and during actuation of said damper motor.

12. In refrigeration equipment, a plurality of condenser units; compressor means for each of said condenser units; refrigerant supply and return means coupling said condenser units to respective condenser means; power driven fan means disposed to direct air through all of the condenser means; movable damper structure for controlling the amount of air permitted to pass through said condenser means by natural convection and during operation of said fan means; apparatus for actuating said fan means and the damper structure, said apparatus including mechanism for moving the damper structure to and from the open and closed positions thereof to regulate the amount of air permitted to pass over the condenser means; control means operably connected to said

mechanism for actuating the latter to move said damper structure a distance in either of the directions of movement thereof, sufficient only to control flow of air over all of said condenser means by natural convection or during operation of said fan means and attempt to maintain the air flow, air temperature and predetermined condensing temperature in balance; and means controlling operation of said fan means for activating and deactivating the latter only after the head pressure of the refrigerant in one of the refrigerant supply and return means has reached preselected high and low levels respectively, and regardless of the positions of said dampers.

13. In refrigeration equipment, a plurality of condenser units; compressor means for each of said condenser units; refrigerant supply and return means coupling said condenser units to respective condenser means; power driven fan means disposed to direct air through all of the condenser means; movable damper structure for controlling the amount of air permitted to pass through said condenser means by natural convection and during operation of said fan means; apparatus for actuating said fan means and the damper structure, said apparatus including mechanism for moving the damper structure to and from the open and closed positions thereof to regulate the amount of air permitted to pass over the condenser

means; control means responsive to the pressure of the refrigerant in one of said refrigerant supply and return means and operably coupled to said mechanism for actuating the latter to move said damper structure a distance in either of the directions of movement thereof, sufficient only to control flow of air over said condenser means by natural convection or during operation of said fan means and attempt to maintain the air flow, air temperature and predetermined condensing temperature of the refrigerant in said one supply and return means, in balance; and means controlling operation of said fan means for activating and deactivating the latter only after the head pressure of the refrigerant in said one supply and return means has reached preselected high and low levels respectively, and regardless of the positions of said dampers.

14. Refrigeration equipment as set forth in claim 13 wherein is provided means connected to said control means for preventing movement of said dampers during periods of inactivation of the compressor means coupled to said one refrigerant supply and return means.

References Cited in the file of this patent

UNITED STATES PATENTS

2,210,325 Newton ---------- Aug. 6, 1940

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,004,402 October 17, 1961

David M. Dart et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 13, line 3, for "above" read -- below --; column 14, line 23, for "with" read -- within --; line 65, for "condenser", second occurrence, read -- compressor --; lines 67 and 69, for "means", each occurrence, read -- units --; same column 14, line 75, for "means", first occurrence, read -- units --; column 15, line 4, for "means" read -- units --; line 16, for "condenser" read -- compressor --; lines 18 and 20, for "means", each occurrence, read -- units --; column 16, line 1, for "means", first occurrence, read -- units --.

Signed and sealed this 16th day of June 1964.

(SEAL)
Attest:

ERNEST W. SWIDER
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