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Wills

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[54] **TEMPERATURE CONTROL SYSTEM WITH MULTIPLE THERMOSTATS**

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[52] **U.S. Cl.** **165/27,** 236/91, 307/39

[51] **Int. Cl.** **F25b 29/00**

[58] **Field of Search** .... 165/14, 22, 26, 27; 236/91 D, 91 F; 307/39

[56] **References Cited**

UNITED STATES PATENTS

3,612,165	10/1971	Haynes	165/26
2,689,932	9/1954	Hornfeck	236/91
2,602,591	7/1952	Wilson et al.	236/91
3,144,991	8/1964	Marchant	236/91
3,616,846	11/1971	Wills	165/26
3,292,689	12/1966	Evans	165/26
3,500,898	3/1970	Gerhart, Jr. et al.	165/26

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[57] **ABSTRACT**

A heating-cooling control system includes thermostats in the discharge and return air passages, and a temperature set dial. A selection circuit energizes one of the thermostats below a preset temperature, and the other thermostat is energized above that temperature. A heat override circuit prevents a call for heat above a certain temperature.

With two compressors, the first compressor is maintained off by a timer circuit for a short time to prevent cycling of the compressor. Another timing circuit briefly delays operation of the second compressor, when the cooling system calls for its operation, to prevent simultaneous energization of both compressors and an excessive demand on the electrical supply line or unit.

6 Claims, 3 Drawing Figures

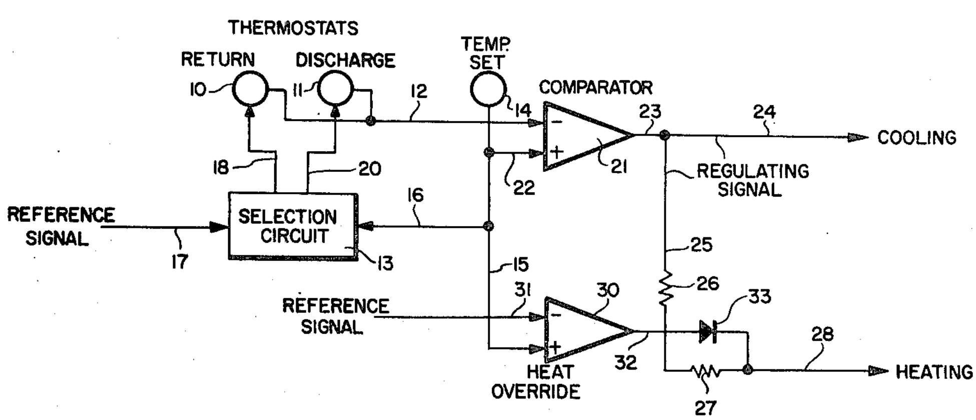
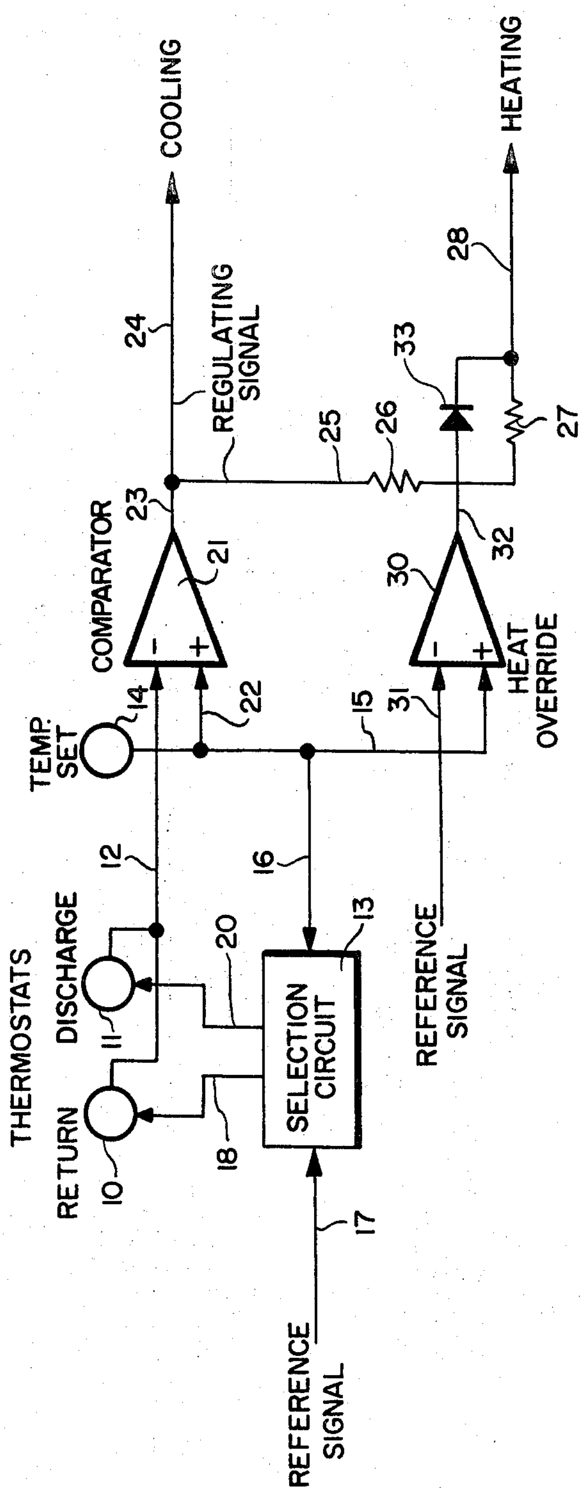
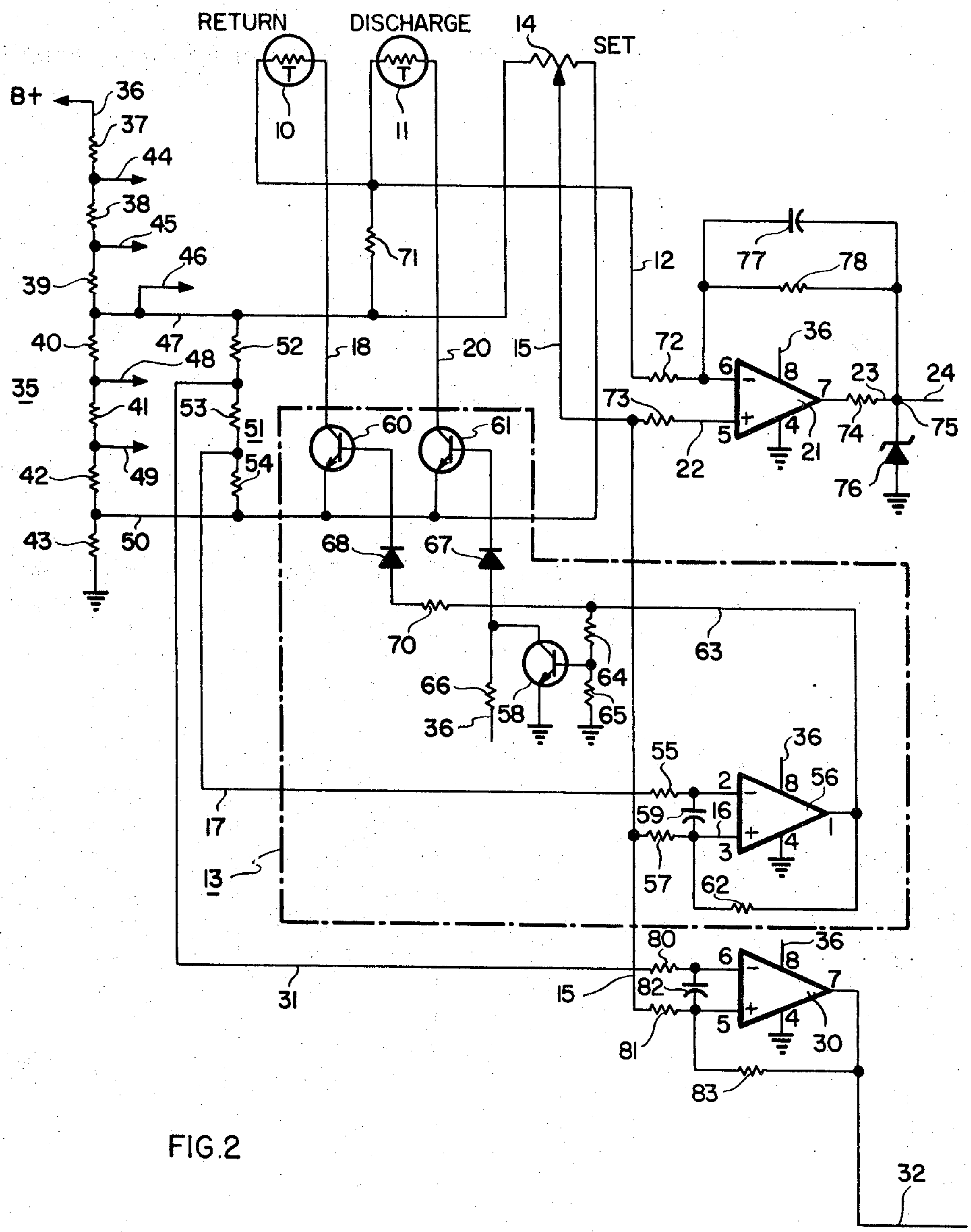


FIG. I


COOLING
HEATING
REGULATING SIGNAL
COMPARATOR
HEAT OVERRIDE
TEMP. SET
THERMOSTATS
RETURN
DISCHARGE
SELECTION CIRCUIT
REFERENCE SIGNAL
REFERENCE SIGNAL
10
11
12
13
14
15
16
17
18
20
21
22
23
24
25
26
27
28
30
31
32
33


RETURN
DISCHARGE
SET
B+
14
10
11
12
15
18
20
35
13
17
31
32
FIG.2

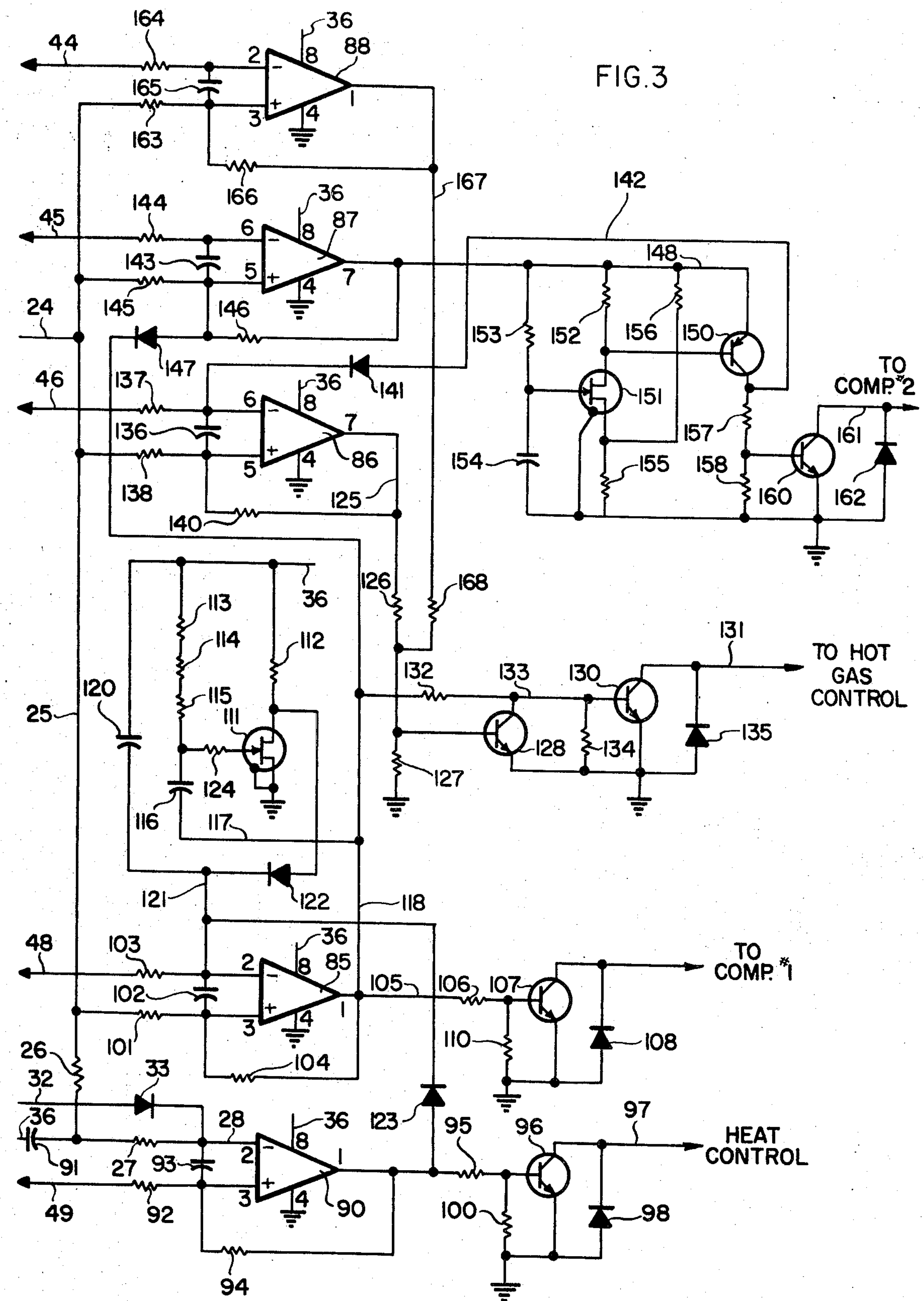

44
164
36
2
8
88
165
1
3
4
163
166
167
142
45
144
36
6
8
87
143
5
7
148
4
24
145
146
153
152
156
150
147
141
46
137
36
6
8
7
151
136
TO
COMP. #2
157
161
5
4
86
154
155
158
160
162
138
125
140
126
168
36
113
114
112
131
TO HOT
GAS
CONTROL
132
133
130
120
25
115
111
124
128
134
135
127
116
117
121
122
118
36
48
103
2
8
85
105
106
107
TO
COMP. #1
102
1
101
3
4
104
110
108
26
32
33
36
28
36
123
95
96
97
HEAT
CONTROL
91
27
93
2
8
1
3
4
49
92
90
100
98
94

FIG.3

TEMPERATURE CONTROL SYSTEM WITH MULTIPLE THERMOSTATS

BACKGROUND OF THE INVENTION

Heating-cooling systems which operate over considerable load variations with multiple compressors have been developed for some time. There are still problems associated with such systems. One problem is with the cooling of fresh produce, such as lettuce, carried in railroad box cars. In general such systems utilize a single thermostat sensing temperature below the top of the produce mass, so that when this sensed temperature indicates suitable cooling of the load, the top layer of the produce is frequently frozen. This frozen material is wasted and must be discarded.

Another problem frequently encountered is the cycling on and off of closely controlled equipment as the sensed temperature varies up and down, just above and below the control point. In a multi-compressor cooling syste, it can happen that more than one compressor is brought on the line simultaneously by a high cooling demand, causing an overload of the electrical supply circuit or equipment.

It is a principal consideration of this invention to provide an improved heating-cooling system which obviates the freezing and destruction of the top layer of produce, when perishables are cooled by the system.

Another important consideration of the invention is to provide a multiple compressor system in which the first compressor energized is not cycled on and off, but delayed in its re-energization, to obviate excess cycling.

Still another important consideration of the invention is the provision of a system which regulates energization and de-energization of the first compressor, loading and unloading of the first compressor, energization and deenergization of a second compressor, and second compressor loading and unloading, in the appropriate sequence to minimize excessive drain in the electrical supply circuit.

SUMMARY OF THE INVENTION

A control arrangement constructed in accordance with this invention is useful to regulate operation of a cooling system which discharges air into a space and receives return air from that space. The control arrangement comprises a first thermostat disposed to provide a first temperature signal indicative of the discharge air temperature, and a second thermostat disposed to provide a second temperature signal indicative of the return air temperature. An adjustable temperature set unit provides a set signal indicating the desired temperature of the space.

In accordance with one aspect of the invention, a selection circuit is connected to receive both the set signal and a first reference signal. This selection circuit completes an operating circuit for the first thermostat when the value of the set signal is less than the value of the first reference signal, and completes an operating circuit for the second thermostat when the value of the set signal is greater than the value of the first reference signal. A comparator circuit is connected to receive both the set signal and the temperature signal from the energized thermostat, and to provide a regulating signal, related to the difference between the set signal and the temperature signal from the energized thermostat, to regulate associated heating and/or cooling equipment.

In addition such an arrangement, when used with at least two compressors, includes a first time-delay circuit to prevent re-energization of the first compressor for a minimum time after the regulating signal decreases and the first cooling control stage indicates the first compressor should be taken off the line. A second time-delay circuit, coupled to the second cooling control stage which governs the second compressor, delays the energization of the second compressor when the regulating signal indicates a call for additional cooling, to prevent simultaneous energization of the compressors and a consequent high demand upon the electrical supply circuit.

THE DRAWINGS

In the several figures of the drawings, like reference numerals identify like components, and in the drawings:

FIG. 1 is a block diagram, partly in schematic form, depicting the general arrangement of a portion of this invention;

FIG. 2 is a schematic diagram which sets out circuit details of components shown generally in FIG. 1; and

FIG. 3 is a schematic diagram which depicts the remainder of the control arrangement of the invention.

GENERAL SYSTEM DESCRIPTION

FIG. 1 shows a general system layout of a portion of the control arrangement of this invention. Conventional equipment, such as a compressor and hot gas conduits utilized in regulating the cooling, and coils or other units for effecting the heating, are not depicted. Similarly the actual discharge and return air vents or conduits are not shown. Such components are well known and can be located in many environments, such as a railroad box car, truck, stationary enclosure, or any other space to be cooled and/or heated by this system.

FIG. 1 shows a first thermostat **11** disposed to provide a first temperature signal which indicates the discharge air temperature. A second thermostat **10** is positioned to provide a second temperature signal which indicates the return air temperature. Both temperature signals do not appear on line **12** simultaneously, because selection circuit **13** completes an operating circuit for only one of the first or second thermostats, so that only one temperature indicating signal appears on line **12** at any one time. A temperature set unit **14**, which can be a simple potentiometer or other device, provides a temperature set signal on line **15** and, over line **16**, to selection circuit **13**. The selection circuit also receives a first reference signal over line **17**. When the value of the set signal is less than the value of the first reference signal, an operating circuit is completed over line **20** for first thermostat **11**. When the value of the set signal exceeds the value of the first reference signal, an operating circuit is completed over line **18** for return air thermostat **10**. This arrangement facilitates the establishment of a crossover point or reference temperature by the value of the reference signal passed over line **17** to selection circuit **13**. For example this reference signal can be set to represent a temperature of 32°F. Then if the temperature set unit **14** is adjusted to call for a temperature above 32°, selection circuit **13** completes an energizing circuit over line **18** for return air thermostat **10**, and allows this thermostat to do the controlling. When the temperature set unit **14** is adjusted to call for a temperature below the cross-over point indicated by the signal on line **17**, then the energizing signal is provided on line **20** so that the discharge air thermostat **11** does the controlling.

Comparator circuit **21** is connected to receive both the set signal, over lines **15** and **22**, and the temperature signal, over line **12**, from whichever one of thermostats **10, 11** is then energized by selection circuit **13**. The comparator stage provides an output or regulating signal on line **23** which is related to the difference between the set signal on line **22** and the temperature signal on line **12**. This regulating signal is passed over line **24** and common line **25** to the cooling control stages, to be described below in connection with FIG. **3**. The regulating signal is also passed from line **25** over resistors **26** and **27**, and line **28** to the heating control circuitry, which will also be described in connection with FIG. **3**.

In accordance with another aspect of this invention a heat override circuit **30** is provided, and has one input connection which receives a second reference signal over line **31**. This second reference signal is usually of a different value then the level of the first reference signal supplied over line **17** to the selection circuit. The level of the second reference signal establishes a base against which the temperature set signal, also received by override circuit **30** from line **15**, is compared to provide a lock-out signal on output conductor **32**. For example, the amplitude of the reference signal on line **31** can be selected to represent a temperature of 20°F. When temperature set unit **14** is adjusted to call for a temperature below 20°, or below any other reference level established by the signal on line **31**, an output signal is provided on line **32** and passed over diode **33** to conductor **28**, to override the regulating signal from line **25**. With this general perspective, a more detailed description of the invention will now be set out.

DETAILED DESCRIPTION OF THE INVENTION

In the left hand portion of FIG. **2** a voltage divider arrangement **35** is shown connected between an energizing conductor **36** and a plane of reference potential, commonly designated ground. Resistors **37–43** are connected in series between conductor **36** and ground to establish different voltage levels or reference signals, utilized to signify different temperature levels against which the actual temperature signals and the set point signal can be compared, and against which the regulating signal applied to the cooling and heating control stages can be referenced. Conductors **44–50**, inclusive, are individually connected to different circuit points in the voltage divider **35** as shown to establish voltage levels, or reference signals, connoting different temperature levels. Another reference unit or voltage divider arrangement **51** includes resistors **52, 53** and **54** connected in series between conductors **47** and **50**. Conductor **17** is connected to the junction of resistors **53** and **54**, and is also coupled over resistor **55** to one input connection of an operational amplifier **56**, connected as a voltage level detector in the thermostat selection circuit **13**. Temperature set unit **14** is a potentiometer having its end connections coupled to conductors **47** and **50**. The other input connection of op amp **56** receives the temperature set signal from the movable tap of potentiometer **14**, over conductor **15**, resistor **57** and conductor **16**. The pin **4** connection of this op amp is grounded, and its **8** pin connection is coupled to conductor **36**, or B+. This is also true (B+ on pin **8**, and pin **4** grounded) for the other op amps **21** and **30** in FIG. **2**, and for the control stage op amps **85–88** and **90** in FIG. **3**. All these units are connected as Schmitt trigger circuits. It will be understood that although different physical conductors are actually used for each stage, the same reference numeral **36** is employed to indicate the connection of the number **8** terminal to B+.

Selection circuit **13** also includes three NPN type transistors **58, 60** and **61**. The output connection of op amp **56** is coupled over a resistor **62** to input connection **3**, and the output connection is also coupled to conductor **63**. The base of transistor **58** is coupled to the common connection between resistors **64** and **65**, which resistors are coupled in series between conductor **63** and ground. The emitter of transistor **58** is grounded and its collector is coupled to the common connection between resistor **66** and the anode of diode **67**. The other end of resistor **66** is coupled to energizing conductor **36**, and the cathode of diode **67** is coupled to the base of transistor **61**. The base of transistor **60** is coupled over diode **68** and resistor **70** to conductor **63**. The emitters of transistors **60, 61** are both connected to conductor **50**, and the collectors of these two transistors are respectively coupled over conductors **18, 20** to the return and discharge thermostats **10, 11**. The symbol T on these thermostats indicate a Thermistor is employed in the preferred embodiment of this circuit. The other connection of each Thermistor is coupled to conductor **12**, and a resistor **71** is connected between conductors **12** and **47** to provide a return circuit for whichever one of Thermistors **10, 11** is energized by circuit **13**.

In circuit **13**, let it be assumed that the value of the first reference signal on line **17** represents a temperature of 32°F. It is further assumed that the temperature called for by set unit **14** is below 32°, and under these conditions it is desired to regulate the system with an output signal from discharge air thermostat **11**. At this time the output signal from stage **56** is low, and there is no gate drive to transistor **60** to complete an operating circuit for Thermistor **10**. However current flows from energizing conductor **36** over resistor **66** and diode **67** to the base of the transistor **61**, driving this transistor on and completing an operating circuit for the discharge air thermostat **11**. Thus under these conditions the temperature signal from Thermistor **11** is passed over line **12** and resistor **72** to the **6** input connection of comparator circuit **21**.

Assuming now that the temperature called for by unit **14** is changed, and is now above 32° or whatever reference level is represented by the signal on line **17**, then the set signal on line **15** is effective over resistor **57** and conductor **16**, to cause amplifier **56** to switch, and the output of this amplifier goes high. This provides gate driver over conductor **63**, resistor **70** and diode **68** to the base of transistor **60**, turning this transistor on to complete an energizing circuit for return air thermostat **10** over line **18**. At the same time, as the signal on conductor **63** goes high, this provides a gate drive signal over the voltage divider circuit **64, 65** for transistor **58**, which is driven on. As transistor **58** conducts it provides a virtual ground at the anode of diode **67**, which robs transistor **61** of the gate drive previously received. Those skilled in the art will appreciate that the transition in control, from one thermostat to the other, can be achieved at any desired temperature by changing the level of the first reference signal provided on line 17.

Comparator circuit 21 receives the set signal over conductor 15, resistor 73 and conductor 22 at its 5 input terminal. This comparator circuit also receives the temperature-indicating signal, over line 12 and resistor 72, from the energized Thermistor. The output connection 7 of this stage is coupled over resistor 74 to a common connection 75. A regulating signal is provided from point 75 over conductor 24 to the associated control circuits to be described in connection with FIG. 3. A Zener Diode 76 is coupled between connection 75 and ground. Capacitor 77 is coupled in parallel with resistor 78, and this parallel circuit is coupled between terminal 75 and input connection 6 of comparator stage 21. The comparator stage operates in a well known manner to provide the regulating signal on conductor 24 and common line 25 as a function of the difference between the set signal received at input connection 5 and the temperature signal received at its other input connection 6.

At the bottom of FIG. 2 heat override stage 30 also comprises an op amp. Its 6 input connection is coupled over a resistor 80 to conductor 31, over which the second reference signal is received. The other input connection 5 is coupled over a resistor 81 to conductor 15, over which the set signal is received. A capacitor 82 is coupled between the two input terminals, and a resistor 83 is coupled between the 5 input connection and the output connection 7, which output connection is also coupled to line 32. This stage 30 functions as the heat override circuit, to provide a lock-nut signal on line 32 to prevent operation of the heat equipment when the temperature called for by the set signal on line 15 is below the value of the temperature represented by the second reference signal on line 31.

Considering now the circuitry depicted in FIG. 3, the regulating signal is received over line 24 and distributed over common conductor 25. In addition the signal from heat override stage 30 is received over conductor 32. Conductors 44–49, inclusive, are connected as already described to the different voltage points in the voltage divider or reference arrangement 35, to provide different reference signals to the control stages in FIG. 3.

The op amps 85, 86, 87 and 88 are connected as cooling control stages to operate or switch in succession and provide actuating output signals to bring on additional cooling as the level of the regulating signal on common line 25 first exceeds that on line 48, then exceeds the level of the reference signal on line 46, next exceeds the reference signal on line 45, and finally is greater than the level of the reference signal established on conductor 44. The other op amp, 90, is a heating control stage used to provide an actuating output signal to associated heating equipment to bring on the heat. In that there is only one heat control stage, this will first be described.

A capacitor 91 is coupled between energizing conductor 36 and the common connection between resistors 26, 27 in the input circuit of op amp 90. The other input connection 3 of this stage is coupled over resistor 92 and conductor 49 to the voltage divider arrangement, to receive a reference signal as already described. A capacitor 93 is connected between the input terminals, and a resistor 94 is coupled between the output terminal 1 and the input connection 3 of this op amp.

Absent any override signa on line 32, the regulating signal on line 25 is applied to the input terminal 2, and the reference signal from conductor 49 is passed to the other input connection 3. When the level of the regulating signal exceeds that of the reference signal, op amp 90 switches and provides a higher or positive output signal at connection 1, which is passed over resistor 95 to rapidly drive on NPN type transistor 96. Conduction of transistor 96 provides an output signal on conductor 97 to actuate the associated heating equipment. For example, this signal can operate a heat controlling relay to pass electrical current through heating coils and provide heat to the enclosed space regulated by the control system of this invention. In the circuit of transistor 96, diode 98 is connected between its collector and emitter as shown, and resistor 100 is coupled between its base and emitter. The emitter, one end of resistor 100, and the anode of diode 98 are connected to ground.

Considering now the first cooling control stage which includes op amp 85, the regulating signal on common line 25 is passed over resistor 101 to the 3 input connection of this stage. Capacitor 102 is coupled between the input connections. The reference signal supplied over line 48 is passed over resistor 103 to input connection 2. The output terminal 1 of this op amp is coupled over resistor 104 to input connection 3.

When the amplitude of the regulating signal on common line 25 passed over resistor 101 to terminal 3 exceeds the value of the reference signal present at input terminal 2, op amp 85 switches to provide a positive or high actuating output signal on conductor 105, which signal is passed over resistor 106 to the base of another NPN type transistor 107. This transistor is gated on to energize the first unit of cooling capacity. By way of example, this signal can complete the energizing circuit for the coil of a relay which puts the first of two compressors on the line, to initiate cooling of the controlled space. The circuit of transistor 107 includes a diode 108 and a resistor 110, connected in a manner similar to diode 98 and resistor 100 in the circuit of transistor 96.

Considering now that the analog regulating signal on line 25 decreases as the space is cooled by the first compressor coming on the line, the signal level on common line 25 decreases and eventually falls below the level of the reference signal on line 48. At this time op amp 85 switches and goes low, so that compressor number one is deenergized at this time. If the analog signal on line 25 suddenly increases again, in a call for cooling, ordinarily the first compressor would immediately be switched on by operation of cooling control stage 85 and transistor 107. To avoid rapid cycling of this compressor, an important feature of this invention is a provision of an "off" time-delay circuit including a field-effect transistor (FET) 111. Considering the circuit of FET 111, energizing conductor 36 is coupled over a resistor 112 to the source of this transistor, and three high-ohm resistors 113, 114 and 115 are coupled in series between conductor 36 and the upper plate of capacitor 116. A table of actual circuit components is set out at the end of the specification, but for the present it is sufficient to note that these three resistors provide a very high value of resistance between conductor 36 and capacitor 116. The lower plate of this capacitor is coupled over conductors **117** and **118** to the output side of op amp **85**, which must go high and provide a positive signal to bring on the first compressor again. Another capacitor **120** is coupled between conductor **36** and a common circuit connection **121**, with diode **122** coupled as shown between circuit point **121** and the source of FET **111**. The drain of this transistor is grounded. Another diode **123** also provides a reference connection between the heating circuit and common circuit point **121**, which is also coupled to the **2** input connection of op amp **85**.

The first call for cooling, which provided the high or positive output signal from op amp **85**, was applied over conductors **118** and **117** to the lower plate of capacitor **116**. This signal allowed the capacitor **116** to be charged from conductor **36** over resistor **112**, the source and gate of FET **111**, and resistor **124** to the upper plate of capacitor **116**. Thus virtually the entire B+ voltage, which was 24 volts positive on line **36** in a preferred embodiment, is developed across capacitor **116** as the first compressor is brought on the line. As the cooling is initially satisfied and op amp **85** switches to a low output signal, this in effect provides a ground or low level signal at the bottom plate of capacitor **116**. In effect this lower plate is now at minus B voltage, but the other side of capacitor **116** is returned through a very high resistance (**113**–**115**) to line **36**. Thus it takes an appreciable time, determined by the high resistance in circuit with capacitor **116**, for this negative voltage on lines **117** and **118** to decrease to the point where the positive switching of op amp **85** can override this voltage. In a preferred embodiment the timing circuit including FET **111** was set to provide approximately a 3-minute off interval of compressor number one. With this circuit the repeated turn-on of the first compressor in the cooling system is prevented, saving undue wear which might otherwise be caused as the regulating signal on common line **25** changed back and forth at a level very close to the reference signal on line **48**.

It is noted that transistor **130** was gated on as the positive signal from op amp **85** was passed over line **118**, resistor **132** and conductor **133** to the base of transistor **130**. Another resistor **134** is coupled between the base and emitter of this transistor, and the diode **135** is connected as shown between the collector and emitter to protect transistor **130**. Conduction of transistor **130** provides a signal on line **131** to energize the hot gas controlling relay, or any other suitable capacity control arrangement. This assumes a system in which the bypass of hot gas to the suction side of the compressor is utilized.

As the level of the regulating signal on line **25** continues to increase and eventually exceeds the level of the reference signal on line **46**, op amp **86** will be switched to provide an output signal over line **125**, resistor **126**, and though resistor **127** to ground. Thus the voltage developed across resistor **127** provides a signal to the gate of transistor **128** which rapidly drives this transistor on and virtually grounds the base of transistor **130**, to cut off this transistor and deenergize the hot gas controlling relay or whatever other hot gas control component may be connected to conductor **131**. In the circuit of op amp **86**, capacitor **136** is coupled between its input terminals. Input connection **6** receives a reference signal over resistor **137**, and the other input connection **5** is coupled over resistor **138** to common conductor **25**, to receive the analog regulating signal. Resistor **140** is coupled between output connection **7** and input connection **5**, and diode **141** is coupled between input connection **6** and conductor **142** to the on-time delay circuit for the second compressor.

As the amplitude of the regulating signal on line **25** further increases and exceeds the level of the signal on conductor **45**, op amp **87** is switched to provide a high output signal at its terminal **7**. This amplifier stage has a capacitor **143** connected between its input terminals, and input connection **6** receives the reference signal over resistor **144**. The regulating signal on common line **25** is coupled over resistor **145** to the other input connection, which is also coupled over resistor **146** to output terminal **7**. A diode **147** has its anode connected to the common connection between resistors **145** and **146** and capacitor **143**, and its cathode coupled to conductor **118**. As the output signal of terminal **7** of stage **87** goes high, this signal is extended over conductor **148** to the emitter of a PNP type transistor **150**. However this circuit includes another FET transistor **151** connected to provide a minimum on-delay, so that the second compressor cannot be energized by a signal of a step function type and an amplitude sufficient to bring on compressors one and two at the same time.

In this second time-delay circuit the source of unit **151** is coupled over resistor **152** to conductor **148**, and the gate of the transistor is coupled to the common connection between a very high resistance **153** and the upper plate of a capacitor **154**, the lower plate of which is grounded. The upper end of resistor **153** is coupled to conductor **148**. The drain of FET **151** is coupled through a resistor **155** to ground. Another resistor **156** is coupled between conductor **148** and the common connection between resistor **155** and the drain of FET **151**. The source of this transistor is coupled to the base of transistor **150**, which has its collector coupled through a series circuit including resistors **157** and **158** to ground. Another NPN type transistor has its emitter grounded and its base coupled to the common connection between resistors **157** and **158**. The collector of this transistor **160** is coupled over line **161** to provide another actuating output signal for bringing the second compressor on the line, as by completing a relay-energizing circuit for this compressor. A diode **162** is coupled between the base and emitter of transistor **160** for circuit protection.

The resistances in the voltage divider circuit including FET **151** are selected so that the potential at the source of this unit is very close to the full B voltage for this circuit as received over conductor **148**. Resistor **156** is "sized" electrically to have a value considerably less than the resistance of resistor **152**. Accordingly the voltage at the drain of FET **151** is considerably lower than the voltage at its source. Thus even though the signal on line **48** is raised when cooling control stage **87** is switched, the voltage applied to the base of PNP type transistor **150** is not changed appreciably at this time, in that the voltage at the drain of FET **151** remains close to ground. It is only after capacitor **151** charges sufficiently to allow FET **151** to conduct, reducing the voltage at the base of transistor **150** and driving this transistor on to provide gate drive for transistor **160**, that the signal is supplied over line **161** to bring the second compressor on the line. Accordingly this circuit functions as an inverse of the timing circuit including FET **111**. This on-time delay circuit prevents simultaneous energization of the compressors to obviate a large drain on the electrical supply, which could blow a fuse or even damage equipment of the motor-generator type which has a limited electrical capacity.

The last cooling stage including op amp **88** is operated when the level of the regulating signal on common line **25** passed over resistor **163** to the 3 input connection of this op amp exceeds the level of the reference signal passed over conductor **44** and resistor **164** to the 2 input connection. A capacitor **165** is coupled between the input connections of this stage, and a resistor **166** is coupled between output connection 1 and input connection 3. Thus as this stage switches and provides a high output signal on conductor **167**, the actuating output signal is passed over resistor **168** to the common connection between resistors **126** and **127**, to regulate the hot gas or other capacity control arrangement.

From this explanation it will be apparent that there is a sequential operation of the cooling control stages **85–88** and the associated cooling equipment as the amplitude of the analog regulating signal on common line **25** gradually increases when the system calls for additional cooling. From the set point established by unit **14**, when the temperature in the control space rises ½°, op amp **85** switches to bring the first compressor on the line and, through transistor **130**, to bring the hot gas on. With an additional half a degree rise to one degree above the set point, op amp **86** is switched high to drive transistor **128** on and rob the drive from transistor **130**, turning the hot gas off. With an additional half a degree temperature rise to a value 1.5 degrees F. above the set point, op amp **87** is switched on to initiate the timing interval so that after FET **151** conducts, transistors **150** and **160** are driven on to bring the second compressor on the line. As soon as op amp **87** conducts, a signal is extended from output pin 7 over resistor **146**, diode **147**, and resistor **132** to energize transistor **130** and bring the hot gas relay on. With a further increase in temperature of half a degree, or a total of two degrees F. above the set point, op amp **88** is switched to provide a signal over line **167** and resistor **168** to drive on transistor **128**, turn off transistor **130**, and shut off the hot gas. With a reversal of the temperature change in the controlled space, the same functions occur in the opposite sequence. The value of the reference signal on line **49** is established so that as op amp **90** is switched, and the heat brought on, when the temperature in the controlled space is one degree F. below that established by the temperature set unit **14**.

To enable those skilled in the art to practice the invention, a table of circuit component identifications and values is set out below. These are given solely to enable those skilled in the art to practice the invention with a minimum of experimentation, and in no way represent a constraint upon the concept or implementation of the invention. The circuit described and illustrated was operated with a d-c potential of 24 volts positive on conductor **36** with respect to ground. The integrated circuits shown, including the units **21**, **30**, **56**, **85–88** and **90**, were all of the Signetics type N5558V. The transistors, other than those identified below, were 2N3416 and the diodes were BAX18. In general the resistors were one-half watt, 5 percent, unless otherwise specified.

Component	Identification or Value	
111,151	2N3822	
150	2N5365	
10,11	Fenwall UUA33J1	
76	1N5247-B	
59,82,93,102	0.1 μf,	25 V.
136,143,165	0.1 μf,	25 V.
77,116,154	2 μf,	200 V.
91,120	50 μf,	16 V.
26	91 K	
27,55,57,64,80,81	10 K	
37	910	
38,39	47	
40,42	100	
41	200	
43,65,100,110,127,134,158	1 K	
52	210	⅛W, 1%
53	32.4	⅛W, 1%
54	261	⅛W, 1%
62,113,114,115,153	20 M	
66,70,92,101,103,137	100 K	
138,144,145,163,164	100 K	
71	10 K	⅛W, 1%
72,73	62 K	
74	510	
78,94,104,140,146,166	4.7 M	
83	10 M	
95,106,112,124,126	7.5 K	
132,152,155,157,168	7.5 K	
156	2 K	

While only a particular embodiment of the invention has been described and illustrated, it is manifest that various modifications and alterations may be made therein. It is therefore the intention in the appended claims to cover all such modifications and alterations as may fall within the true spirit and scope of the invention.

What is claimed is:

1. A control arrangement for regulating operation of a cooling system which discharges air into a space and receives return air from the space, which control arrangement comprises:

a first thermostat disposed to provide a temperature signal indicative of the discharge air temperature;

a second thermostat, disposed to provide a second temperature signal indicative of the return air temperature;

a temperature set unit, adjustable to provide a set signal indicating the desired temperature of the space;

a selection circuit, connected to receive both the set signal and a first reference signal, which selection circuit completes an operating circuit for the first thermostat when the value of the set signal is less than the value of the first reference signal, and completes an operating circuit for the second thermostat when the value of the set signal is greater than the value of the first reference signal; and

a comparator circuit, connected to receive both the set signal and the temperature signal from the energized one of the thermostats, and to provide a regulating signal, related to the difference between the set signal and the temperature signal from the energized thermostat, to regulate associated equipment.

2. A control arrangement as claimed in claim **1**, and further comprising a heat override circuit, connected to receive both the set signal and a second reference signal, operative to provide a lock-out signal to prevent operation of associated heating equipment when the temperature called for by the set signal is below the value of the temperature represented by the second reference signal.

3. A control arrangement for regulating operation of a cooling system which discharges air into a space and receives return air from the space, which control arrangement comprises:

a first Thermistor disposed to provide a first temperature signal indicative of the discharge air temperature;

a second Thermistor, disposed to provide a second temperature signal indicative of the return air temperature;

a temperature set potentiometer, adjustable to provide a set signal indicating the desired temperature of the space;

a selection circuit, including a voltage level detector connected to receive both the set signal and a first reference signal, a first transistor connected to complete an operating circuit for the first Thermistor when the value of the set signal is less than the value of the first reference signal, and a second transistor connected to complete an operating circuit for the second Thermistor when the value of the set signal is greater than the value of the first reference signal; and

a comparator circuit, connected to receive both the set signal and the temperature signal from the energized one of the Thermistors, and to provide a regulating signal, related to the difference between the set signal and the temperature signal from the energized Thermistor, to regulate associated equipment.

4. A control arrangement for regulating operation of a cooling system which discharges air into a space and receives return air from the same space, including first and second thermostats disposed to provide temperature signals indicating the discharge and return air temperature, a temperature set unit providing a set signal to indicate the desired space temperature, a selection circuit completing an operating circuit to only one of the thermostats as a function of the set signal and a first reference signal, a comparator circuit receiving the set signal and the temperature signal from the energized thermostat to provide on a common line a regulating signal which is a function of the difference between the set signal and the actual temperature signal from the energized thermostat, and at least two cooling control stages, each having an input portion coupled to the common line, and each having an output circuit individually coupled to different cooling components, to bring on one of the different cooling components at different amplitude levels of the regulating signal on the common line.

5. A control arrangement for regulating operation of a cooling system by comparing a temperature set signal with an actual temperature signal and providing a regulating signal, related to the difference between the set signal and the actual temperature signal to regulate cooling equipment including at least two compressors through a plurality of cooling control stages, which control arrangement comprises:

a common line connected to receive the regulating signal;

a first cooling control stage, having a first input connection coupled to the common line and a second input connection connected to receive a first reference signal, to provide an actuating output signal when the regulating signal exceeds the first reference signal and bring the first compressor on the line;

a second cooling control stage, having a first input connection coupled to the common line and a second input connection coupled to receive a second reference signal, to provide an actuating output signal when the regulating signal exceeds the second reference signal and bring the second compressor on the line; and

a first time-delay circuit, coupled to said first cooling control stage, effective to maintain said first controlling stage in the off condition for a predetermined minimum time interval after the regulating signal on the common line has decreased below the value of the first reference signal, to avoid excess cycling of the first compressor.

6. A control arrangement as claimed in claim **5**, and further comprising a second time-delay circuit, coupled to said second cooling control stage, effective to prevent said second cooling control stage from providing an actuating output signal for a predetermined minimum time interval after the regulating signal on the common line exceeds the value of the second reference signal, to prevent simultaneous energization of the first and second compressors and obviate a large drain on the power supply.

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