Nov. 11, 1952 C. M. SANDERS 2,617,598

CONTROL APPARATUS

Filed June 3, 1949 2 SHEETS—SHEET 1

FIG. 1

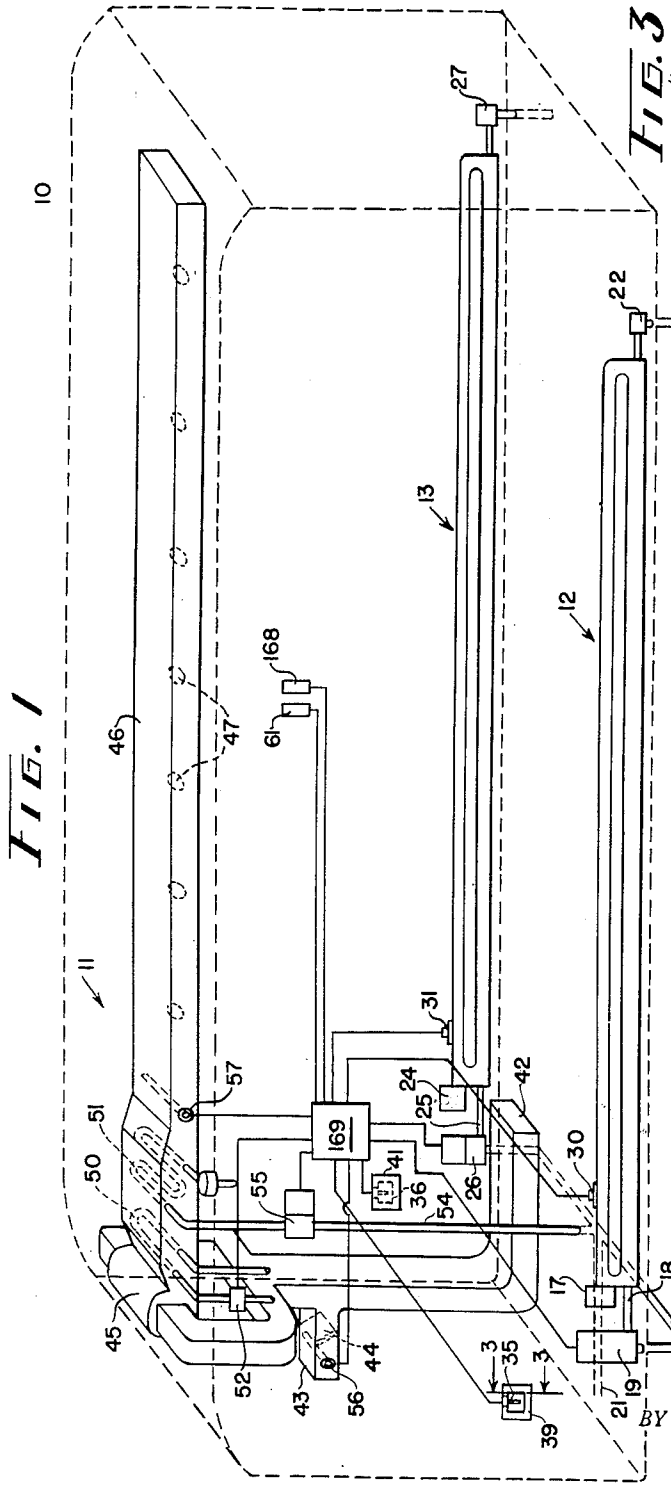


FIG. 3

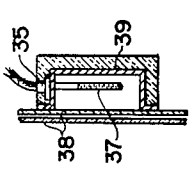
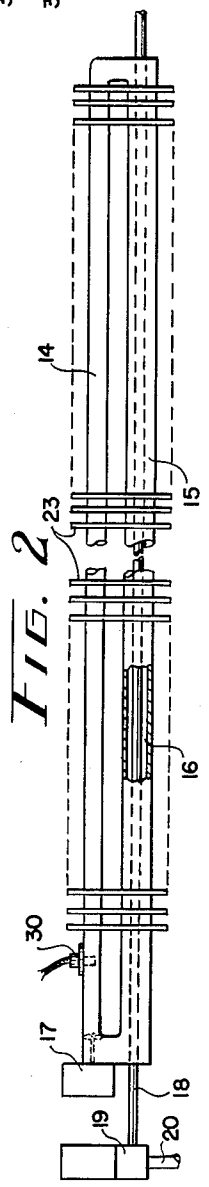


FIG. 2



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Filed June 3, 1949 2 SHEETS--SHEET 2

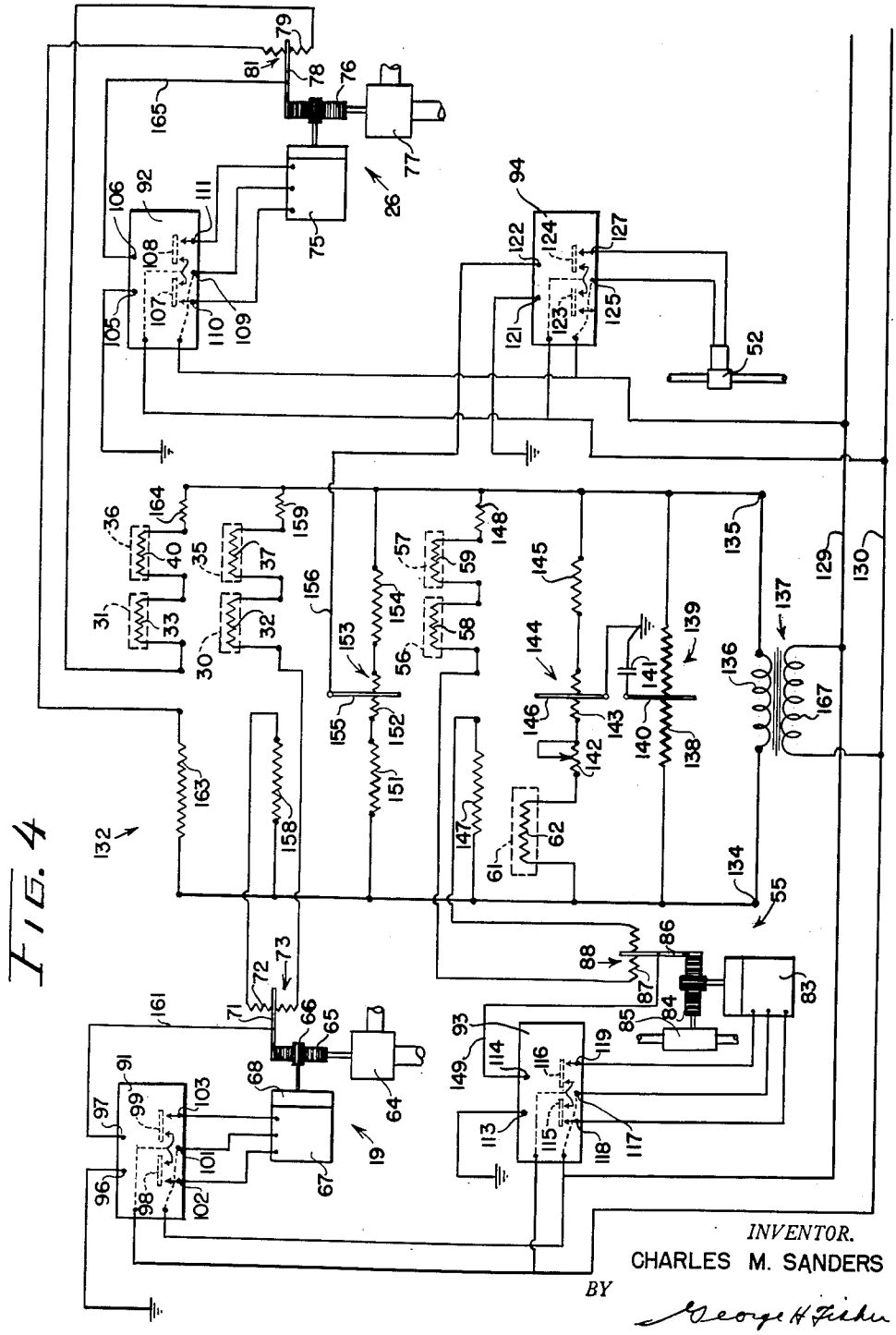


FIG. 4

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UNITED STATES PATENT OFFICE

2,617,598

CONTROL APPARATUS

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Application June 3, 1949, Serial No. 97,001

9 Claims. (Cl. 237—5)

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The present invention relates to an improved temperature control apparatus particularly useful for railroad cars.

The copending patent application of Wissmiller et al., Serial No. 698,014, filed September 19, 1946, now Patent No. 2,583,524, granted January 22, 1952, relates to a temperature control system for railway cars wherein individual heat exchangers along the wall of the car are controlled in a manner to offset the effects of changing outside temperature, sun, wind, and the like on the respective walls. The overhead heating system is relied on for the remainder of the heat load and for pickup purposes. This system gives excellent control but tends to be slow in picking up car temperature after standby because the control of the side wall heat exchangers is independent of space temperature. The present control apparatus overcomes this difficulty by combining the network circuits for the side wall heat exchangers with the overhead control network in such a manner that a deviation in space temperature effects the entire control system but, when the space temperature is satisfied, the side wall heat exchangers are independently controlled to meet their respective demands.

It is thus an object of this invention to provide an improved temperature control system especially adapted for railway passenger cars.

It is a further object to provide a temperature control system for a space having a plurality of temperature changing devices wherein all of them cooperate to vary the space temperature but wherein certain of the devices thereafter are operated at temperatures determined by outside weather conditions, or a condition indicative of said outside conditions.

It is an additional object to provide a network circuit having a branch with a common output connection and a plurality of parallel branches with separate output connections, with each of the separate output connections being adapted to control separate devices.

It is also an object to provide a temperature control system particularly adaptable to railway cars and arranged to use all available heating means to restore car temperature upon a deviation in car temperature but wherein important components are normally controlled by conditions other than car temperature.

These and other objects will become apparent upon a study of the following specification and drawings wherein:

Figure 1 is a schematic view of a railway car incorporating the present invention.

Figure 2 is an elevation view, with parts in section, of a side wall heat exchanger as used in Figure 1.

Figure 3 is a sectional view taken on the line 3—3 of Figure 1.

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Figure 4 is a schematic wiring diagram on the present apparatus.

Referring to Figure 1, car 10 includes an overhead heating and cooling apparatus generally designated by the numeral 11, and further includes side wall heat exchangers 12 and 13 extending the length of the occupied space. Heat exchangers 12 and 13 are disposed along the lower portions of the two side walls and, because they are near the floor, are sometimes referred to as the floor heaters.

As best shown in Figure 2, heat exchanger 12 includes horizontal conduits 14 and 15 connected at their end to form a closed loop. A suitable heat exchange liquid 16, such as a mixture of ethylene glycol and water, is circulated through said loop by a conventional motor driven circulator 17. Any suitable expansion means, such as a closed tank, expansible bellows, or the like, not shown, may be connected to each heat exchanger to accommodate the expansion of the heated liquid. Liquid 16 is heated by a steam pipe 18 extending through lower conduit 15, pipe 18 being connected through a motorized valve 19 and pipe 20 to the train steam line 21. The condensate formed in pipe 18 is discharged through a conventional steam trap 22 (Figure 1). To increase the effective radiating area of heat exchanger 12, fins 23 may be secured to conduits 14 and 15 in any desired manner. Also, for a purpose which will appear, resistance thermostat 30 is inserted in conduit 14 in a manner to respond to the temperature of the circulating liquid 16.

Although only heat exchanger 12 has been described in detail, heat exchanger 13 is identical therewith and includes a circulator 24, a steam pipe 25, a motorized valve 26, a steam trap 27 and a resistance type insertion thermostat 31. While the components of this heat exchanger are the same as those of 12, they have been given different numbers to reduce confusion in the following description.

Insertion thermostat 30 comprises a temperature responsive resistor 32 wound on a suitable core, provided with the necessary connections, and protected from the liquid 16 by a suitable well. Thermostat 31 is identical to 30 and includes a temperature responsive resistor 33. Of course, any devices which vary an electrical resistance in response to temperature changes of the sidewall heaters may be used instead of thermostats 30 and 31. Immersion thermostats 30 and 31 cooperate with window thermostats 35 and 36, respectively, in the normal control of their respective heat exchangers. Window thermostat 35, Figure 3, comprises a temperature responsive resistor 37 and is mounted adjacent the inside of the inner pane of the window glass 38 by an insulated box 39 having an

open side toward said glass, said resistor thus responding to the temperature of the inside surface of the inner glass, sun effects, and other factors influencing car wall temperature, such as wind. Obviously, a better response to wind and outdoor temperature is had where a single pane window is used. Thermostat 35 may be similarly mounted adjacent the inside surface of the outer skin of the car, this arrangement involving less response to sun effects. Window thermostat 36 is similar to 35 and includes a temperature responsive resistor 40 and an enclosing insulated box 41.

The overhead apparatus 11 comprises a return air inlet duct 42, a fresh air inlet duct 43 controlled by a damper 44, a blower 45 and a distributing duct 46, said duct 46 having outlet openings 47. A cooling coil 50 is located in duct 46 near the blower and a heating coil 51 is located just downstream from said cooling coil. Cooling coil 50 is supplied with refrigerant, chilled brine or the like, from a source not shown, under the control of a conventional solenoid valve 52. Heating coil 51 is supplied with steam from the train steam line 21 through pipe 54 under the control of a motorized valve 55. A resistance thermostat 56 is arranged in the fresh air inlet duct 43 and therefore responds to outdoor temperature, and the similar thermostat 57 is arranged in duct 46 downstream from coil 52 and thus responds to the temperature of the air discharged into the car.

Outside air thermostat 56, often called a ductstat, comprises a temperature responsive resistor 58 carried on a suitable core and having the necessary connection facilities. Resistor 58 is preferably formed of nickel wire, or material having similar properties, although, obviously, any material having a suitable temperature coefficient of resistance may be used. Discharge air thermostat 57 includes a temperature responsive resistor 59 and is similar in construction to thermostat 56. Room thermostat 61 is another element of the present control apparatus and comprises a mounting means and a temperature responsive resistor 62, plus the necessary connections. As with the other thermostats herein described, temperature responsive resistor 62 may be of any suitable sort, such as nickel wire, but, for the purpose of this disclosure, all of the temperature responsive resistors are considered to have a positive temperature coefficient of resistance. Obviously, thermostat 61, or a ductstat modification of 61, may be located in the return air duct 42 rather than in the middle of the car, as shown.

Motor valves 19 and 26 are identical and valve 55 is likewise similar. Motor valve 19, for example, includes angle valve 64 having a reciprocable stem to which is attached a rack 65, rack 65 being operable by pinion 66 driven by motor 67 through a gear train 68. Motor 67 represents any conventional reversible motor and, for the purpose of this disclosure, may be of the sort shown in Figure 2 of Upton Patent 2,423,534, issued July 8, 1947. In addition to adjusting valve 64, rack 65 also adjusts wiper 71 across resistor 72 of follow up potentiometer 73.

In a similar fashion, reversible motor 75 of motorized valve 26 not only adjusts the rack and stem 76 of angle valve 77, but also adjusts wiper 78 across resistor 79 of follow up potentiometer 81. Likewise, motor 83 of motorized valve 55 simultaneously operates rack and stem 84 of valve 85 and adjusts wiper 86 across resistor 87 of follow up potentiometer 88. For this disclosure, it may be assumed that valves 19, 26 and 55 are closed when their respective racks and stems are in a lowermost position and solenoid valve 52 is closed when deenergized.

Amplifiers 91, 92, 93 and 94, used to control motors 64, 75 and 85 and solenoid 52, respectively, are preferably all alike and of a discriminator sort wherein one relay or another is energized when a signal is impressed upon it, the relay operated depending upon the phase relation of the input signal. While any amplifier of the sort described may be used, the one described in Figure 2 of the aforementioned Upton patent has been found satisfactory.

Amplifier 91 has input terminals 96 and 97, terminal 96 being grounded, and includes relays 98 and 99, relay 98 being energized when a signal of one phase is imposed on terminal 97 and relay 99 being energized when a signal of opposite phase is imposed on said terminal. Relay 98, when pulled in, causes motor 67 to be energized through common output terminal 101 and output terminal 102, motor 67 then running in a valve opening direction. Relay 99, when energized, causes the motor to be energized through terminals 101 and 103, the motor then running in a valve closing direction.

Motor 75 is controlled by amplifier 92 in the same manner as motor 67, amplifier 92 having a grounded input terminal 105 and another input terminal 106, and relays 107 and 108 control the energization of motor 75 through output terminals 109, 110 and 111, relay 107 operating to drive motor 75 in a valve opening direction and relay 108 operating to close the valve, as above described.

Motor 83 is likewise controlled by amplifier 93 in a manner similar to the control of motor 67, amplifier 93 having input terminals 113 and 114, relays 115 and 116 and output terminals 117, 118 and 119, motor 83 also being driven in a valve opening direction when a signal of one phase is impressed on terminal 114 and in a valve closing direction by a signal of opposite phase.

Amplifier 94 has input terminals 121 and 122, relays 123 and 124, and operates to energize solenoid valve 52 through output terminals 125 and 127 when a proper signal is impressed on terminal 122.

Amplifiers 91, 92, 93 and 94 are all supplied with current by suitable connections to line wires 129 and 130.

The source of the signals used for controlling the aforementioned amplifiers is an electrical network circuit 132. Network circuit 132 has input terminals or sides 134 and 135, these terminals being energized by secondary winding 136 of transformer 137. While the terminals or sides 134 and 135 are shown as connecting wires, it seems obvious that effectively the same circuit would result if all the branches were connected to the same terminals, the present arrangement being chosen, however, for clarity and more ease in explaining the functions of the circuit. The lowermost branch of the network comprises a high resistance resistor 138 of potentiometer 139 connected across terminals 134 and 135, wiper 140 of the potentiometer being connected through capacitor 141 to ground. This branch is used for balancing the capacity effects of the network when the system is first put in operation.

The next branch of the circuit comprises, reading from terminal 134 to terminal 135, resistor

62 of room thermostat 61, control point adjusting rheostat 142, resistor 143 of calibrating potentiometer 144 and fixed resistor 145. Wiper 146 of potentiometer 144 is connected to ground. The next parallel branch of the circuit, reading upwardly, and extending between terminals 134 and 135, comprises fixed resistor 147, resistor 87 of follow-up potentiometer 88, resistor 58 of outside air thermostat 56, resistor 59 of discharge air thermostat 57 and fixed resistor 148. Wiper 86 of follow-up potentiometer 88 is an output terminal for this branch of the network and is connected by wire 149 to input terminal 114 of amplifier 93.

The cooling control branch of network 132, extending between terminals 134 and 135, comprises fixed resistor 151, resistor 152 of potentiometer 153 and fixed resistor 154, wiper 155 of potentiometer 153 being connected by wire 156 to input terminal 122 of amplifier 94.

The first sidewall branch, just above the cooling branch, extends between terminals 134 and 135 and comprises fixed resistor 158, resistor 72 of follow-up potentiometer 73, resistor 32 of insertion thermostat 30, resistor 37 of window thermostat 35 and fixed resistor 159. Wiper 71 of follow-up potentiometer 73 comprises an output terminal for this branch of the network and is connected by wire 161 to input terminal 97 of amplifier 91. The uppermost branch, for the other sidewall heat exchanger, likewise extends between terminals 134 and 135 and comprises a fixed resistor 163, resistor 79 of follow-up potentiometer 81, resistor 33 of insertion thermostat 31, resistor 40 of window thermostat 36 and fixed resistor 164. Wiper 78 of follow-up potentiometer 81 constitutes the output terminal for this branch of the network and is connected by wire 165 to input terminal 106 of amplifier 92.

Primary winding 167 of transformer 137 is connected to line wires 129 and 130 and thereby energized.

The following resistance values for the above circuits are approximate and are given for illustration only, similar values having been found to work satisfactorily.

Resistor:	Ohms resistance
138	50,000
62	500
142	10
143	30
145	500
147	500
87	6
58	25
59	20
148	145
151	500
152	30
154	500
158	500
72	6
32	[1]63
37	[1]250
159	187
163	500
79	6
33	[1]63
40	[1]250
164	187

[1] With double glazed windows.

Capacitor:	Microfarads capacity
141	.01

A separate thermostat 168, set for a relatively low temperature such as 60°, is provided for standby operation of valves 19 and 26, or other heat exchange surface, but this part of the system has nothing to do with the present invention and is therefore not described.

The components of network 132, with the exception of the thermostats and follow-up potentionmeters, and the amplifiers are mounted, for convenience, in a central control panel 169, as shown in Figure 1.

When the above described system has been installed in a car, each portion of the network circuit is adjusted to give a minimum signal for its respective amplifier and then the capacity balance potentiometer 139 is adjusted to reduce these minimum signals to their minimum values, thereby compensating for the capacity effects and the like due to long lead wires to remote components and other such factors that normally tend to give an appreciable residual signal. Once this adjustment has been made, it remains fixed and thus this portion of the network 132 has no part in the normal operation of the circuit.

To more fully describe the present apparatus, its function will now be considered.

Operation

With car 10 under standby control, it may now be placed in readiness for occupancy by connecting line wires 129 and 130 to a suitable source of alternating current, not shown, the various components of the system then being energized by the circuits previously described. However, before proceeding with this description, let it now be assumed that the analysis of the network circuit will be made at a half cycle instant when the potential of the left side, or terminal 134, of the network is, for instance, positive, and the right side, or terminal 135, is negative. Obviously, at the next half cycle instant, these relations will be reversed but, by considering the balance conditions of the network in terms of potential at the aforementioned half cycle instant, the phase relations are readily understood. Thus, although this description is in terms of potentials, the phase relations of the circuit are really being considered.

It may also be assumed that rheostat 142 is adjusted to require a 70° temperature in the car, with heating being required when the temperature is below this value and with cooling being provided when the temperature is above said value. Further, assume that liquid 16 in side wall heaters 12 and 13 is controlled to 70° when windowstat 35 or 36 responds to 70° and that each degree below 70° for the respective windowstat requires the liquid in its heat exchanger to increase in temperature 4°. Also, thermostats 56 and 57 are assumed to be so related that the air discharged through duct 46 will rise 1⅕° above 70° for every degree drop in outside temperature below 70°.

Further, assume that a positive signal impressed on terminals 97, 106, 114 and 122 of amplifiers 91, 92, 93 and 94 will result in energizing relays 99, 108, 116 and 124, respectively, of the amplifiers, while a negative signal (one of opposite phase) will energize relays 98, 107, 115 and 123, respectively.

With the system now in operation, and with the car temperature low, the outside temperature low, the discharge air temperature low, and the liquid temperature of the side wall heat exchangers low, it appears that the car tem-

perature will be increased in the following manner. With the car temperature low, the resistance of resistor 62 is low, therefore terminal 134 of the network is less positive in potential than normal and terminal 135 is more negative than normal, this being due to the comparative low resistance in the branch of the network to the left of wiper 146, said wiper being grounded. With this condition existing, and emphasized because the resistance of resistor 58 is relatively low due to a low outside temperature and the resistance of resistor 59 of thermostat 57 is relatively low due to the low discharge air temperature, wiper 86 tends to be negative relative to ground, hence a negative signal is impressed on terminal 114 of amplifier 93. As previously related, a negative signal on amplifier 93 causes relay 115 to be energized thereby energizing motor 83 in a direction to open valve 55 and to drive wiper 86 to the right across resistor 87 of follow-up potentiometer 88. This movement tends to diminish the resistance on the positive side of the network and to increase the resistance of the negative side but, because of the low space temperature, the low outside temperature and the low discharge air temperature, it seems likely that the negative signal will persist even though wiper 86 to driven to the right extreme of resistor 87. Thus, air at the maximum temperature available from the system will be supplied through outlets 47 into car 10 from the overhead system 11.

With terminal 134 less positive than normal and terminal 135 more negative than normal, wiper 155 of potentiometer 153 tends to be negative, hence a negative signal is impressed on terminal 122 of amplifier 94, thus pulling in relay 123. However, relay 123 exercises no control on the present system, hence no cooling is provided.

With terminal 134 less positive than normal and terminal 135 more negative than normal, and with the resistance of resistor 32 relatively low and the resistance of 37 also relatively low, wiper 71 tends to be negative, hence a negative signal is impressed on terminal 97 of amplifier 91, thereby pulling in relay 98 of said amplifier and causing motor 67 to operate in a valve opening direction. Opening valve 19 causes a greater flow of steam through pipe 18 to thereby increase the temperature of liquid 16 and additionally, the opening of valve 19 causes wiper 71 to be adjusted upwardly across resistor 72, thereby lowering the resistance on the positive side of the network and increasing the resistance on the negative side of the network. Under the conditions assumed, however, it seems likely that the negative signal will persist even though wiper 71 is advanced to the top of resistor 72, hence the full available heat is supplied to side wall heat exchanger 12. In a similar fashion, a negative signal tends to be impressed on terminal 106 of amplifier 92, thereby pulling in relay 107 and driving motor 75 in a direction to open valve 26 and moving wiper 78 upwardly across resistor 79 in an attempt to rebalance the circuit. Thus, the fully opend valve 26 likewise causes side wall heat exchanger 13 to operate at its full capacity. With side wall heat exchanger 12 and 13 operating at full capacity and with the maximum available capacity of the overhead system 11 being used, the temperature of car 10 should rise rapidly.

As the car temperature rises, the resistance of resistor 62 increases and terminal 134 becomes more positive relative to ground and terminal 135 becomes less negative relative to ground, hence the above described negative signals are diminished. Further, even ahead of car temperature, the temperature of liquid 16 in the side wall heat exchangers 12 and 13 rises and the temperature of the air discharged through conduit 46 increases hence, although the effect of these changes will be discussed individually, it seems obvious that the changes are taking place simultaneously. Although the car temperature rises less rapidly than does the discharge air temperature and the temperature of the liquid 16, the effect on the network is more pronounced as resistor 62 increases in value because of its relatively greater authority. As resistor 62 increases in resistance value and terminal 134 becomes more positive and terminal 135 less negative, this tends to diminish the negative signals to the various amplifiers but, normally, the car temperature must rise within a few degrees of its desired temperature before the effects of the higher resistance values of resistors 59, 32 and 33 can be felt. However, as the value of resistor 62 approaches normal, the relatively high resistance of 59, as well as the extreme right position of wiper 86, causes the resistance between wiper 86 and terminal 135 to be relatively high hence wiper 86 now becomes positive relative to ground and a positive signal is thus imposed on terminal 114 of amplifier 93. When the negative signal impressed on amplifier 93 diminished to a predetermined value, relay 115 dropped out and now, with a sufficient positive signal on terminal 114 to energize relay 116, motor 83 is energized in a direction to drive the valve 55 closed and to move wiper 86 to the left across resistor 87. As wiper 86 moves across resistor 87, it adds resistance to the positive side of the network and subtracts resistance from the negative side of the network thereby diminishing the positive signal and, when this signal is diminished below a predetermined value, relay 116 drops out and motor 83 stops. The partial closing of valve 55 restricts the flow of steam to coil 51 and thereby causes a reduction in the temperature of the air being discharged into the car.

With a full flow of steam through valve 19, liquid 16 becomes quite hot, therefore resistor 32 has a relatively high resistance value and tends to make wiper 71 positive, this tendency being increased by the position of wiper 71 near the top of resistor 72, whereby none of the resistance of resistor 72 is in the positive side of the network and all of the resistance is in the negative side of the network branch. Although the relatively high temperature and resistance of 32 would normally cause a positive signal on wiper 71, the signal has remained negative in the description so far due to the relatively low resistance value of 62. However, as the car comes up to temperature and this resistance value increases, terminal 134 becomes more positive and terminal 135 becomes less negative relative to ground than before. At some point of balance, the negative signal on terminal 97 of amplifier 91 will diminish below the point necessary for holding relay 98 energized hence it will drop out, thus deenergizing motor 67. With a further increase in resistance of 32, or an increase in resistance of 62, the signal on 71 becomes sufficiently positive to pull in relay 99, thereby energizing motor 67 in a direction to close valve 19 and to move wiper 71 downwardly across resistor 72 far enough to

diminish the positive signal to the point that relay 99 drops out and again deenergizes motor 67. In a similar fashion, the increase in resistance of resistor 33 causes a closing operation of valve 26 until the network branch is rebalanced sufficiently to drop out relay 108. As the car temperature approaches its desired value, as described above, the rate of supply of heat is diminished, thus avoiding overshooting of temperature.

Upon the car temperature reaching its desired value, it then appears that the resistance of 62 is just sufficient to restore the potential of terminals 134 and 135 to the value at which the system is calibrated thus, for the present, resistor 62 may be considered the same as a fixed resistor and without influence on the network.

As the car temperature has been rising toward its desired value, motor 83 has been gradually closing off valve 55 to lower the temperature of the air discharged through conduit 46, in the manner above described, and now, with resistor 62 satisfied, motor 83 will drive valve 55 to a position wherein sufficient heat will be supplied by coil 51 to maintain the resistance value of 59 sufficiently far above normal (70°) to offset the decrease in resistance of resistor 58 below normal due to the relatively low outside temperature. Then, should the discharge temperature be relatively high, wiper 86 tends to be positive relative to ground, hence relay 116 is energized and operates motor 83 to close valve 55 and to advance wiper 86 to the left across resistor 87, to thereby balance the network branch. Exactly the same effect would take place if the resistance value of 58 should increase due to a rise in outside temperature and, should the outside temperature fall below its previous value or in the event of a decrease in discharge temperature, the lessened resistance of 58 or 59, or both, tends to cause wiper 86 to become negative relative to ground to thereby pull in relay 115 and drive motor 83 in a valve opening direction. As above described, upon resistor 62 reaching its normal value due to a satisfied car temperature, valve 55 is operated to hold a predetermined discharge temperature relative to outside temperature, this temperature value being that calculated to maintain stable conditions in the car.

With resistor 62 at its normal resistance value, there is no signal from the network at wiper 155, and both the relays of amplifier 94 are open, hence there is no cooling provided.

When the car temperature is satisfied and the resistance of 62 normal, valve 19 is adjusted to maintain a predetermined relation between the resistance values of 32 and 37, a relatively low resistance of either 32 or 37, or both, tending to cause wiper 71 to be negative and therefore causing an opening of the valve by pulling in relay 98. Also, an increase in resistance of either or both of these resistors tending to cause wiper 71 to become positive relative to ground, causes a closing of valve 19 by energizing relay 99. Thus, as the temperature of thermostat 35, and therefore the resistance of 37, is dependent upon outside temperature, wind, solar effects and the like, the resistance of this thermostat is not varied by the present system hence this branch of the network tends to control valve 19 in a manner to adjust the temperature and resistance of thermostat 30 to compensate for the variations from normal of resistor 37. Thus, with the temperature affecting resistor 37 at a value of 50° F., or 20° below normal, the temperature of thermostat 30 must increase to 150°, or 80° above normal, to restore equilibrium conditions.

Likewise, thermostats 31 and 36 control amplifier 92 and motor valve 26 in a manner to increase the temperature and resistance of thermostat 31 as the temperature and resistance of thermostat 36 decreases. While it might seem, at first glance, that valves 19 and 26 could be controlled in parallel from one set of thermostats, attention is directed to the fact that thermostats 35 and 36 not only respond to outside temperature, by responding to the inside temperature of the window or the like, but also respond to the effects of sun and wind. Therefore, if the sun should shine on the side of the car where window thermostat 35 is located, the sun would tend to increase the temperature and resistance of resistor 37 and thereby require a somewhat lower temperature of the liquid in side wall heater 12 followed by a reduction in the temperature and resistance of resistor 32, to therefore compensate for the heat added to that side of the car by the sun shining on it. The sun shining on the other side of the car would have a similar effect on the control of heat exchanger 13. Likewise, wind on the car, due to natural wind, motion of the car, or both, and when the outside air temperature is lower than car temperature, tends to lower the temperatures of thermostats 35 and 36 by varying amounts depending on its incidence, magnitude, temperature and the like and tends to require additional heat from the sidewall heaters.

Should, for some reason or other, the car temperature increase beyond the desired value even though it is still cold outside, the added resistance of resistor 62 tends to make terminal 135 more positive than normal and terminal 135 less negative than normal, hence wipers 86, 155, 71 and 78 all tend to become positive relative to ground, hence tending to pull in relays 116, 124, 99 and 108. This tends to close valves 55, 19 and 26 and to energize valve 52, thus not only restricting the heat supplied to the car but also bringing on cooling. As a practical matter, because the refrigeration compressor is usually controlled by outside temperature and does not start operating until the outside temperature rises to a predetermined value, such as 60°, no actual cooling may be provided even though valve 52 is opened if the outside temperature should be below 60°, for instance. Obviously, as the outside temperature rises to 70° and the car temperature tends to rise above 70°, valves 55, 19 and 26 are all driven closed by the predominant positive signal on their respective amplifiers. The positive signal on wiper 155, and therefore on amplifier 94, causes energization of relay 124 and the consequent opening of valve 52 to provide the necessary cooling.

As above described, by connecting the side wall heat control apparatus into the same network used for controlling the overhead part of the system, all of the heating capacity of the car is available to increase car temperature when desired yet, when the car temperature becomes satisfied, the overhead heating apparatus and the two side wall heaters are independently controlled to meet their respective needs, hence, the present system provides for the independent control of the two side wall heaters and the overhead apparatus, as in the aforementioned Wissmiller et al. application, and yet is able to combine all of these heaters together when needed, thereby providing a system highly effective in operation and very

flexible under adverse conditions. Because many substitutions and equivalents will become apparent upon a study of this disclosure, the scope of this invention should be determined only by the appended claims.

I claim as my invention:

1. A temperature control system for a space enclosed by a plurality of outside walls wherein forced air heating apparatus and a plurality of heat radiating means are used for heating said space, said forced air heating apparatus having an outside air inlet and discharging into said space, space temperature responsive impedance means, separate electrical impedance means responsive to the temperature of each of said radiating means, electrical impedance means individually responsive to the temperature of each of a plurality of outside walls, impedance means responsive to outside air temperature, impedance means responsive to the temperature of the air discharged into said space, a voltage dividing network circuit having input connections and a plurality of parallel branches, the first of said branches including said space temperature responsive means and a first output connection, a second branch of said network including said outdoor temperature responsive impedance and said discharge air temperature responsive impedance and a second output connection, a plurality of branches each including an impedance responsive to the temperature of one of said radiating means and an impedance responsive to outside wall temperature and each having an output connection, electric amplifier means connected to said first and second output connections and arranged to control said forced air heating apparatus, and additional electric amplifier means arranged to be connected to said first output connection and each of said plurality of output connections for controlling each of said heat radiating means.

2. A temperature control system for a space enclosed by walls, at least one of the walls being exposed to the outside, forced air heating apparatus and a heat radiating means disposed along said outside wall for heating said space, said forced air heating apparatus having an outside air inlet and discharging into said space, space temperature responsive electrical impedance means, electrical impedance means responsive to the temperature of said radiating means, electrical impedance means responsive to a temperature indicative of the temperature of the outside surface of said outside wall, impedance means responsive to outside air temperature, impedance means responsive to the temperature of the air discharged into said space, a voltage dividing network circuit having input connections and a plurality of parallel branches, the first of said branches including said space temperature responsive means and a first output connection, a second branch of said network including said outdoor temperature responsive impedance and said discharge temperature responsive impedance and a second output connection, and a third branch including the impedance responsive to the outside wall temperature and the impedance responsive to the temperature of said radiating means and having a third output connection, amplifier means connected to said first and second output connections and arranged to control said forced air heating apparatus, and amplifier means connected to said first output connection and said third output connection for controlling said heat radiating means.

3. A temperature control system for a space enclosed by a plurality of walls including an outside wall, forced air heating apparatus for heating said space, electrically controlled means for controlling said apparatus, heat radiating means for heating said space, said heat radiating means being disposed along said outside wall, additional electrically controlled means for controlling heat radiating means, separate follow up potentiometers connected to and operable by each of said electrically controlled means, space temperature responsive electrical impedance means, electrical impedance means responsive to the temperature of said radiating means, electrical impedance means responsive to a condition indicative of outside wall temperature, a voltage dividing network circuit having input connections and a plurality of parallel branches, the first of said branches including said spaced temperature responsive means and a first output connection, a second branch of said network including the follow up potentiometer for the electrical control means for the forced air heating apparatus, the wiper of said potentiometer constituting a second output connection, a third branch including the means responsive to the temperature of said radiating means and the impedance means responsive to the condition indicative of outside wall temperature and additionally including the follow up potentiometer for the electrical means used for controlling said radiating means, the wiper of this potentiometer constituting a third output connection, amplifier means connected to said first and second output connections for controlling said electrically controlled means, and amplifier means connected to said first and third output connections and arranged to control said additional electrically controlled means for the heat radiating means.

4. A temperature control system for a space enclosed by walls wherein a forced air heating apparatus and a heat radiating means is used for heating said space, electrically controlled means for controlling said apparatus, additional electrical means for controlling said heat radiating means, separate follow up means operable by each of said electrical means, space temperature responsive electrical impedance means, impedance means responsive to the temperature of said radiating means, impedance means responsive to a condition indicative of the temperature of one of said walls, an impedance responsive to outdoor temperature, an impedance responsive to the temperature of the air discharged into said space by said apparatus, a voltage dividing network circuit having a plurality of parallel branches including in a first branch said space temperature responsive means and a first output connection, a second parallel branch including said impedance responsive to the condition indicative of the temperature of said heat radiating means and the impedance responsive to the condition indicative of the side wall temperature and the follow up means for the additional electrical means used for controlling the heat radiating means, the wiper of said follow up means constituting a second output connection, a third parallel branch including said outdoor temperature responsive impedance and said discharge temperature responsive impedance and the follow up potentiometer for the electrical means used for controlling the forced air heating apparatus, the wiper of this potentiometer being a third output connection, an amplifier means connected to said first and second output connections and arranged to

control the additional electrical means for the heat radiating means, and an amplifier means connected to said first and third output connections for controlling the electrical means used for controlling said forced air heating apparatus.

5. A temperature control system for a railway car having an enclosed space heated by a side wall heat exchanger and a forced air heating apparatus, motor actuated means for controlling the temperature of said side wall heat exchanger, additional motor means for controlling said forced air heating apparatus, an individual follow up potentiometer connected to and operable by each of said motor means, a space temperature responsive means, impedance means responsive to a condition indicative of the temperature of the side wall heat exchanger, an impedance responsive to a condition indicative of the side wall temperature of the car, an impedance responsive to outdoor temperature, an impedance responsive to the temperature of the air discharged into said space by said forced air apparatus, a voltage dividing network circuit having input connections and a plurality of parallel branches, the first of said branches including said space temperature responsive means and a first or common output connection, a second parallel branch including said side wall heat exchanger condition responsive means and said side wall condition responsive means and the follow up potentiometer of the motor means used for controlling said side wall heat exchanger, the wiper of said follow up means constituting a second output connection, a third parallel branch including said outside air temperature responsive impedance and the discharge temperature responsive impedance and the follow up potentiometer for the motor means used for controlling the forced air heating apparatus, the wiper of this follow up potentiometer being a third output connection, amplifier means connected to said first and second output connections and arranged to control the motor actuated means for the side wall heat exchanger, and another amplifier connected to said first and third output connections and arranged to control the motor actuated means for said forced air heating apparatus.

6. A temperature control system for a railway car having an enclosed space heated by a plurality of side wall heat exchangers and a forced air heating apparatus, individual motor actuated means for controlling the temperature of said side wall heat exchangers, additional motor means for controlling said forced air heating means, follow up potentiometer means actuated by each of said motor means, each of said follow up potentiometer means including a resistor and a wiper, a space temperature responsive means, impedance means responsive to the temperature of each of said side wall heat exchangers, impedance means responsive to the temperatures of the outer surfaces of a plurality of the side walls of the car, a network electrical circuit having input connections and a plurality of parallel branches, the first of said branches including said space temperature responsive means and a first output connection, a second parallel branch including the follow up potentiometer of the motor means for controlling said forced air means, the wiper of said potentiometer constituting a second output connection, a third parallel branch including a side wall heat exchanger temperature responsive means and a side wall temperature responsive means and the resistor of the potentiometer actuated by the motor used for controlling one of said side wall heat exchangers, the wiper of said potentiometer constituting a third output connection, a fourth branch of said network circuit including another of said side wall heat exchanger temperature responsive means and another of said wall temperature responsive means and the resistor of the follow up potentiometer actuated by the motor means for controlling said side wall heat exchanger, the wiper of this latter potentiometer being used for a fourth output connection, amplifier means connected to said first and second output connections for controlling the additional motor means for said forced air heating apparatus, and amplifier means connected to said first, third and fourth output connections and individually controlling the motor means which control the side wall exchangers.

7. Temperature control apparatus for a railway car having overhead heating apparatus and floor heat radiating means, first actuator means for controlling said overhead apparatus, second actuator means for controlling said floor heating means, first means responsive to a condition indicative of car temperature, second means responsive to a condition indicative of outside temperature, third means responsive to a condition indicative of the temperature of said floor heat means, and a balanceable network circuit means having a plurality of parallel branches connecting said first temperature responsive means in control of said first actuator means and for connecting said second and third temperature responsive means in controlling relation to said second actuator means for independent control thereof, said first temperature responsive means being in a different branch than said second and third temperature responsive means, said first temperature responsive means being arranged to alter the balance conditions of the entire network circuit.

8. An electrical network circuit having a plurality of voltage dividing parallel branches, a first branch of said network having an output connection common to the network and including a condition responsive impedance means arranged so that variations in its impedance value will affect the balance of the entire network, a second one of said parallel branches including a second output connection and having a plurality of condition responsive impedances so arranged that changes in the impedance sum of said plurality of impedances will cause a signal to appear at said second output connection and a third one of said parallel branches having a third output connection and also having a plurality of condition responsive impedances arranged so that changes in the impedance sum of said impedances in the third branch will cause a signal to appear at said third output connection, the signals appearing at said second and third output connections being normally compared with said common output connection but having a negligible effect on each other.

9. An electrical network circuit comprising a plurality of parallel branches, the first of said branches having a common output connection and a condition responsive impedance on one side of said output connection, a second parallel branch having a second output connection and a plurality of condition responsive impedances in series, said plurality of impedances being arranged on one side of said second output connection, a third parallel branch having a plu-

rality of condition responsive impedance means and a third output connection, said last named plurality of impedances being arranged on one side of said third output connection, and input connections for said network connected to each of said parallel branches, said network being so arranged that a variation in the impedance of the connection responsive means in the first branch causes an output signal to appear across said common output connection and the other output connections and a variation in the impedance of the condition responsive impedances of the second or third branch is capable of causing an output signal across the output connection of the respective branch and the common output

connection but has a negligible effect on the remaining output connection.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,282,442	Whitlock	May 12, 1942

FOREIGN PATENTS

Number	Country	Date
540,087	Great Britain	Oct. 6, 1941