United States Patent

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[73] Assignee **Raypak Company, Inc.**

[54] **MULTIPLE-BOILER TEMPERATURE CONTROL SYSTEM HAVING BOILER SEQUENCING, REVERSE ORDER FIRING, AND INDIVIDUAL BOILER MODULATION WITH OUTDOOR TEMPERATURE RESET**
12 Claims, 3 Drawing Figs.

[52] **U.S. Cl.** **122/1,** 122/448
[51] **Int. Cl.** **F22b 35/00**
[50] **Field of Search** ..... 122/1 (R), 448 (R), 448 (B)

[56] **References Cited**
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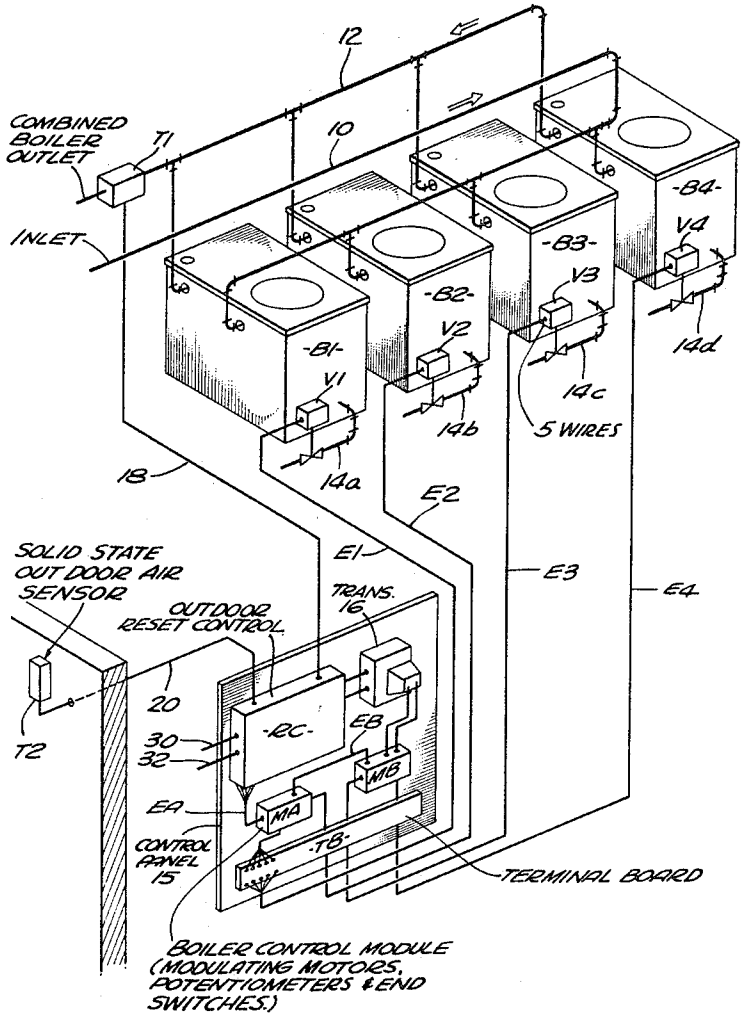
ABSTRACT: The invention is a multiple-boiler system having *N* boilers with sequencing control. Each boiler has modulating control by way of control of a gas valve. The boilers are brought on in sequence, or fired in sequence in response to load requirements, each boiler being modulatingly controlled while on. The control is from boiler outlet temperature, reset by outdoor temperature. At predetermined intervals the sequence of firing of boilers is reversed so as to tend to even out the firing time of all boilers. The control system is constructed to accommodate itself to use of commercially available control instrumentalities.



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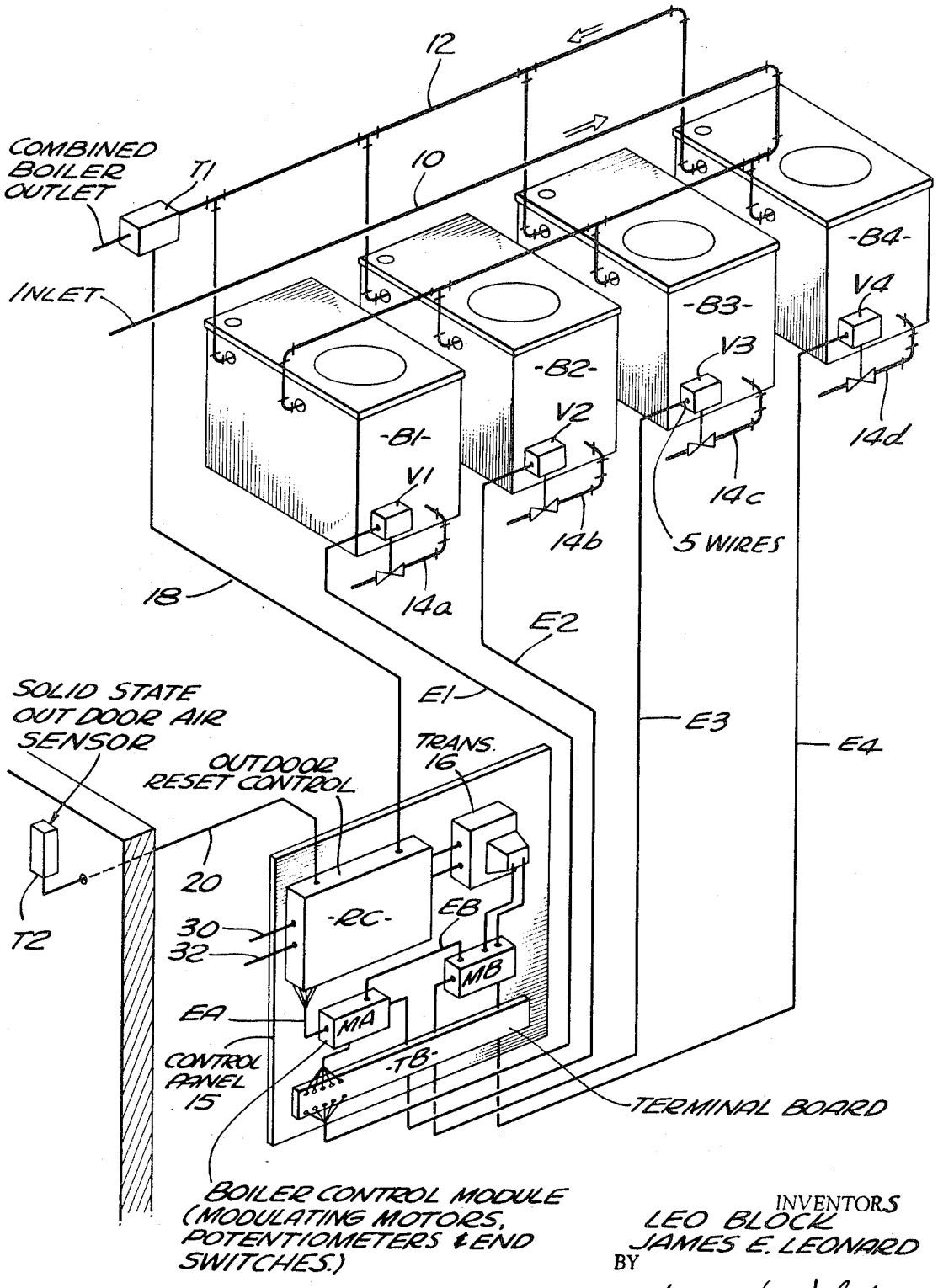
SHEET 1 OF 3

FIG. 1.



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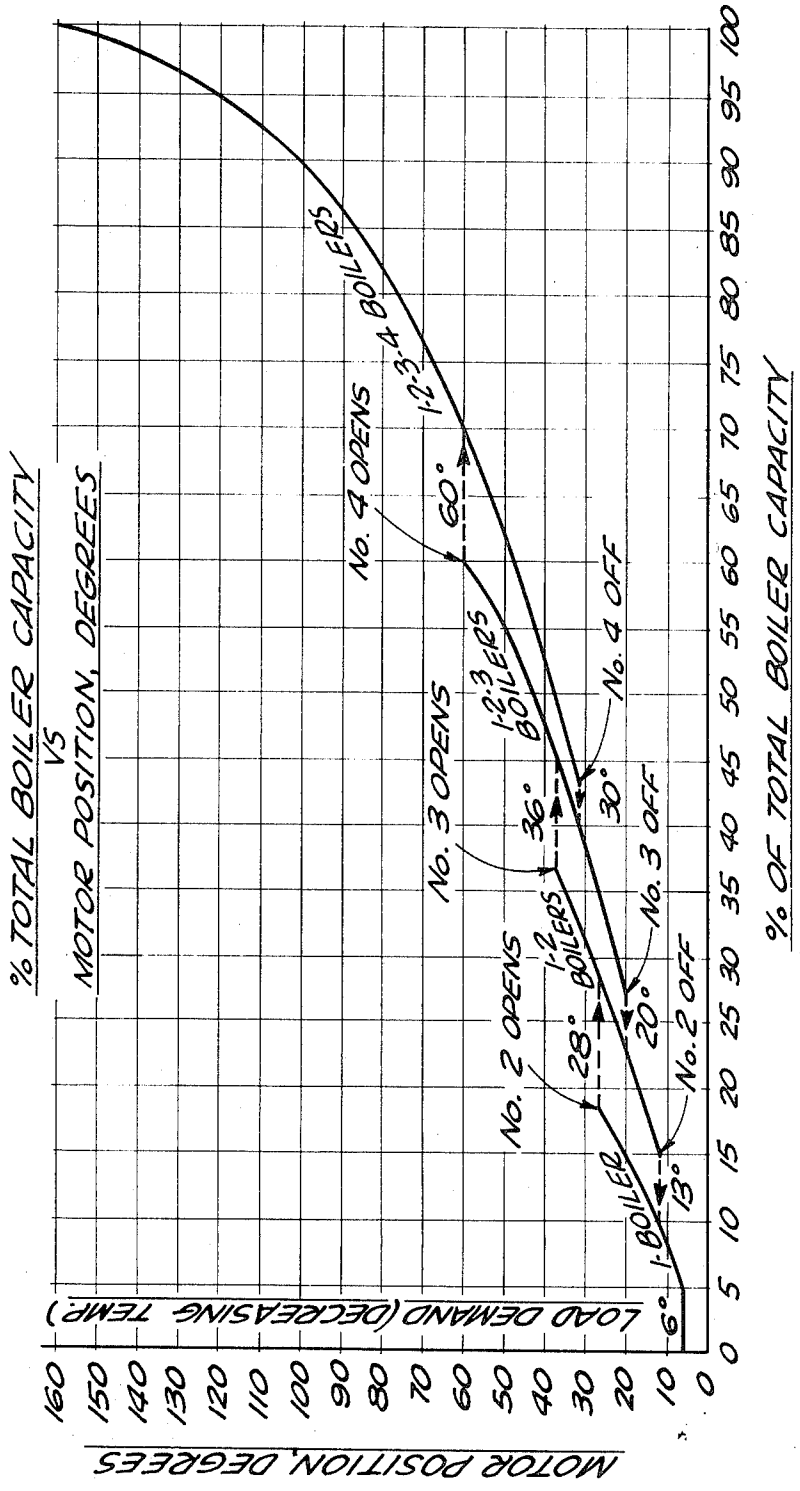

FIG. 2.

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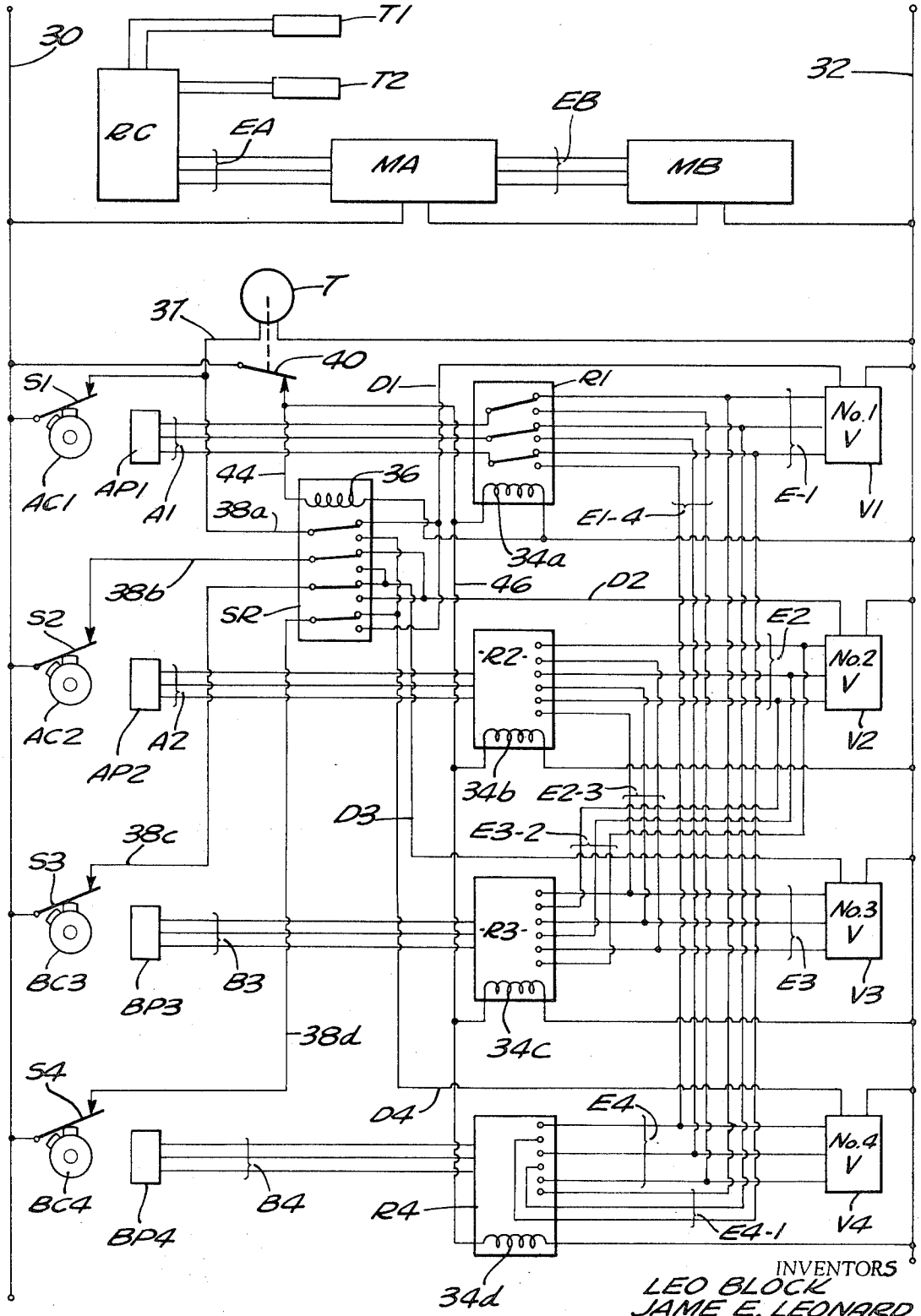

FIG. 3.

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MULTIPLE-BOILER TEMPERATURE CONTROL SYSTEM HAVING BOILER SEQUENCING, REVERSE ORDER FIRING, AND INDIVIDUAL BOILER MODULATION WITH OUTDOOR TEMPERATURE RESET

SUMMARY OF THE INVENTION

The invention is a system for controlling the operation of a battery of boilers (heating units). The system is applicable to any number of boilers, that is, N boilers. The system embodies boiler sequencing or staging. If one heating boiler is used for a heating system it has to be of sufficient capacity to handle the system under extreme cold weather conditions. This condition would occur perhaps 1 percent of the heating season. As a result, the single boiler would frequently be cycling on and off. In preference to one large boiler it is desirable to use multiple boilers, such as four or five smaller boilers. Using multiple boilers, the control system would bring the boilers on one at a time as the load demands increase, until all boilers are on the line under extreme conditions. This method of sequencing or staging has a number of advantages, including that of minimizing boiler on-off cycles; achieving fuel savings associated with the operation and making possible better control of temperature.

In the system of the invention reverse order of firing is employed. This method reverses the numerical order of firing or coming on of the boilers at intervals. This avoids the result of the first boiler on the line accumulating much more operating time than other boilers. This method evens out the operating hours on boilers.

Outdoor reset control is a method of control in which the control of the boiler or system is adjusted or reset in accordance with outdoor temperature, so as to adjust the capacity in accordance with heating load requirements. By decreasing the boiler outlet temperature the overall heating capacity of the system is reduced, and this adjustment or reset may be made in accordance with outdoor temperature.

Typically, multiple-boiler systems are provided with on-and-off controls for each boiler, for example, valve controls that are on and off. In the system of the herein invention, in the multiple-boiler system, modulating control is provided for each individual boiler, preferably by way of modulation of a valve which may be a gas-firing valve. Thus, there is modulating control of the capacity over the entire range of capacity of the whole battery of boilers. Thus, the capacity of the complete battery of boilers can be more closely controlled and adjusted to follow the load curve determined by outdoor temperature or other load conditions. This advantage is gained while at the same time gaining the basic advantage of having sequenced multiple boilers rather than a single boiler. The invention embodies reverse order firing to gain the advantage of that type of operation as referred to in the foregoing, the system being set up so that when the order of firing is reversed, there is modulating control of individual boilers but in the reverse order. The system as described readily adapts itself to convenience in setting or adjusting the points in the load demand curve at which boilers come on in sequence, so as to produce the most effective and efficient results from the standpoint of economy of operation and closeness of control of the temperature being controlled.

Similarly, the system adapts itself to convenience of setting or adjusting the points at which boilers come off the line as load demands decrease, so as again to adjust the capacity to the load curve, these settings or points in the system of the invention being different upon decreasing load than upon increasing load, the system as stated, readily adapting itself to the accomplishment of this purpose.

In the preferred form of the invention the control system embodies proportioning-type control motors which actuate switches which energize modulating gas valves. These switches are a commercial type of cam-operated switch which close at a particular degree position of their cams and open at another degree position. When a successive boiler in the sequence is brought on, at that time, its gas valve is opened to a predetermined position, by way of example, slightly less than half open. Thus there is a sudden step increase in total boiler capacity which would be too great for the immediate load demands. However the valve that has just opened is under modulating control and it and preceding valves in the sequence are modulated in the reverse direction to overcome the effect of the step increase in total capacity, being modulated back to a position wherein the total capacity corresponds to the load demands. Thus in this manner over the entire range of boiler capacity of the multiple boilers the capacity is modulated to conform to load demands.

In the light of the foregoing, the primary object of the invention is to obtain the advantages of modulating control of boiler capacity in a multiple-boiler system wherein the boilers are sequenced, and wherein reverse order firing is provided for, the modulating control being of the type embodying outdoor reset. In other words, the advantages of modulating control and the ability to adjust the capacity to the load curve are realized in a system wherein the basic advantages attendant to boiler sequencing, reverse order firing, and outdoor reset control are also realized.

Another object is to make possible the results referred to in the foregoing in a system which accommodates itself to and makes possible the use of control components that are readily available commercially without the design and construction of special instrumentalities.

Another object is to make possible and facilitate the convenient adjustment of the output capacity to follow the load curve, both under increasing and decreasing load conditions.

Another object is to provide a control system for implementing the preceding object wherein successive boilers are brought on at predetermined angular positions of control motors whereby to create step increases in total boiler capacity, all of the boilers however being under modulating control at the time of the step increase whereby the system is able to modulate back to a capacity corresponding to the load demand.

Further objects and additional advantages of the invention will become apparent from the following detailed description and annexed drawings wherein:

FIG. 1 is a schematic illustrative view of a typical multiple-boiler installation, equipped with the control system of the invention;

FIG. 2 is a chart or graph showing a curve representing boiler capacity versus load demand in terms of angular position of a control motor or motors;

FIG. 3 is a wiring diagram illustrating in greater detail the control system of FIG. 1.

The exemplary form of the invention as described herein is a multiple-boiler system for providing hot water for heating, the boilers being gas fired and controlled by modulating gas valves. It is to be understood, however, that the invention could be similarly adapted in a cooling or dehumidifying system wherein the temperature of the medium is cooled rather than heated. In other words, the principles of the invention could be employed with multiple temperature-changing units that effect cooling or dehumidifying rather than heating, it being convenient and explanatory to describe the invention in terms of the exemplary multiple-boiler system.

In FIG. 1 the characters B1, B2, B3, and B4 represent typical heating units or boilers, in which water is heated and delivered to a header which conveys the water to an area to be heated. Numeral 10 designates an inlet or return waterline, having a branch connection as shown to each heater (boiler). Numeral 12 designates an outlet line or header having an outlet connection from each boiler as shown. In the outlet line is a temperature sensor T1.

The heaters or boilers as shown typically are gas fired, the boilers having gas control valves V1, V2, V3, and V4 in gaslines 14*a*, 14*b*, 14*c*, and 14*d*.

The controls comprise an outdoor reset controller RC which may preferably be of the potentiometer type, such as,

for example, of the type shown in detail in U.S. Pat. No. 2,257,471. Power is supplied by way of a transformer 16. The character T2 is an outdoor temperature sensor or thermostat. The temperature sensor T1 is connected to the reset controller by way of a cable 18, and the temperature sensor T2 is connected by way of a cable 20.

The characters MA and MB designate control motors of the type adapted to control from a potentiometer, the control system or circuitry being of the proportioning type, as illustrated in U.S. Pat. Nos. 2,257,471 or 2,109,062. These motors embody a rebalancing potentiometer so that they are positioned in accordance with the position taken by the control potentiometer, the control circuit being a bridge circuit. The reset controller RC controls motor MA through circuit EA. The motor MA has a control potentiometer in it which controls the motor MB through the circuit EB, so that the motor MB follows the position of motor MA.

On the shaft of motor MA are two control potentiometers and two cam switches which are shown in FIG. 3, the potentiometers being identified by the characters AP1 and AP2, and the switches being identified as S1 and S2, these switches being operated by double cams AC1 and AC2. These switches are of a readily available standard commercial type which close at one angular position and open at another as determined by the setting of the double cams. On the shaft of motor MB there are also two potentiometers identified in FIG. 3 by the characters BP3 and BP4, and also two end switches S3 and S4 operated by double cams BC3 and BC4. The reference character TB in FIG. 1 identifies the terminal board. From the terminal board control cables leading to each of the valves V1, V2, V3, and V4, are identified by the characters E1, E2, E3, and E4. As will be described, an interval timer, and appropriate relays are provided as part of the control panel 15 whereby the type of control as described in the foregoing is realized. The components as described are mounted on a control panel 15.

Preferably, the motors MA and MB are of a readily available commercial type, such as the type manufactured by Minneapolis Honeywell Regulator Co., and identified by the trademark MODUTROL. The shafts of these motors and the potentiometers that they drive in the system as herein described, operate through a range of 160°.

FIG. 2 is a chart or graph showing a boiler capacity curve versus load demand in terms of angular position of the control motors in degrees. The curve as shown in the chart represents the controlled capacity of the multiple-boiler system as load demands increase, and also the adjusted or controlled boiler capacity as the load demands decrease, and as will be described more in detail presently. The control system as illustrated schematically in FIG. 1 is capable of realizing the controlled boiler capacity curves illustrated in FIG. 2.

FIG. 3 is a schematic wiring diagram illustrating the control system of FIG. 1 more in detail. As illustrated schematically in FIG. 3, the temperature sensors T1 and T2 might be simply thermostatic bulbs actuating bellows elements that in turn adjust a potentiometer slider of the conventional type, such as shown in the patents referred to herein. More elaborate types of controls might, of course, be used. The reset controller RC controls the motor MA through the three-wire circuitry EA and the motor MA controls and positions the motor MB through the three-wire circuitry EB. Power for the control system is provided from line wires 30 and 32.

As previously described, the double cams AC1 and AC2 are on the shaft of motor MA and the double cams BC3 and BC4 are on the shaft of motor MB. As described, the shafts of these motors rotate through a range of 160°. The double cams provide for closing of the switches S1 through S4 at one angular position and opening of the switches at another angular position, as will be described.

The characters R1, R2, R3, and R4 identify control relays or potentiometer control relays whereby the potentiometers AP1, AP2, BP3, and BP4 control the positioning of the four valves V1 through V4. The relay R1 is a three-pole, double-throw relay as shown, having a winding 34. Potentiometer AP1 is connected to the three poles of relay R1 by a three-wire circuit A1. Relays R2, R3, and R4 are like R1, the connections to their poles from the other three control potentiometers being by way of the three-wire circuit A2, B3, and B4.

The three poles of relay R1 cooperate with three in and three out contacts as shown, one set of these contacts being connected to valve V1 by a three-wire circuit E1, and the other set of three contacts being connected to the valve V4 by three-wire circuit E1–4. Thus, as may be seen, the relay R1 has two positions in one of which potentiometer AP1 is connected to valve V1, and in the other position this potentiometer is connected to valve V4. The relays R2, R3, and R4 each have two positions also. In one position of relay R2, it connects potentiometer AP2 to valve V2 through a three-wire circuit E2, and in the other position it connects this potentiometer to valve V3 through three-wire circuit E2–3 3. In one position of relay R3, it connects potentiometer BP3 to valve V3 through three-wire circuit E3, and in its other position it connects this potentiometer to valve V2 through three-wire circuit E3–2. In one position of relay R4, it connects potentiometer BP4 to valve V4 through three-wire circuit E4, and in its other position it connects this potentiometer to valve V1 through three-wire circuit E4–1. Thus, as may be seen, when the relays R1 through R4 change position, they reverse the order of control, that is, they reverse the sequence from the order V1, V2, V3, V4 to the reverse order, V4, V3, V2, V1. The control from motors MA and MB remains the same with respect to the valve control potentiometers.

The character SR designates a sequence-reversing control relay which reverses the sequence of control of power to the valves V1 through V4. This relay is a four-pole relay as shown, having four in and four out contacts and a winding 36. The four poles of the relay are connected respectively as shown to the switches S1 through S4 by way of wires 38A, 38B, 38C, and 38D. Relay SR has four in and four out contacts. One set of contacts connects to and controls the supply of power to the valves V1 through V4 by way of connections or wire D1 through D4. When relay SR changes its position with its poles engaging the other set of four contacts, the switches S1 through S4 are connected to the valves V1, V2, V3, and V4 in reverse order, that is, switch S1 now controls valve V4; S2 controls valve V3; switch S3 controls valve V2; and switch S4 controls valve V1, as is apparent from FIG. 3.

The character T is a 36-hour timer which actuates a switch 40, which controls the winding 36 of relay SR, as well as the windings 34*a* through 34*d* of the relays R1 through R4. Every 36 hours it reverses the order of firing as will be described. Switch 40 controls relay winding 36 by way of wire 44. It connects to wore 46 also, windings 34*a* through 34*d* being connected in parallel to wire 44 and to line wire 32. The timer T may be controlled from switch S1 by wire 37 or directly from the line.

The exact manner of control as has been referred to in detail will be clearly understood from the following description of operation.

OPERATION OF THE CONTROL SYSTEM

The operation of the system as shown at FIG. 3 should be considered in connection with the chart FIG. 2.

As explained, the motors MA and MB rotate through an angular range of 160°. In the 0° position all boilers are off. If the outside temperature is above 70° and the combined boiler outlet temperature is hot enough, no demand is made on the boilers. If the outdoor temperature drops and/or if the combined boiler water temperature drops, the sensors will transmit their signals to the control RC. This will cause motor MA to rotate. The degree of rotation is proportional to the demand signalled by the sensors. As explained, motor MB is driven by MA. At light load, the motors will remain between the 0° and 28° positions with the No. 1 boiler B1 on only. At extreme

cold temperature, that is, extreme heating load requirements, the motors rotate to their extreme position of 160°, and at that point all boilers are on at full capacity.

Valves V1 through V4 do not operate (they remain closed) unless they are energized by closure of switches S1 through S4. If these valves are not energized they remain in a closed position, regardless of the position of their controlling potentiometers.

Referring to switches S1 through S4, the following are the angular opening and closing positions of these switches. S1 opens and closes at 6°. S2 closes at 28° and opens at 13°. S3 closes at 36° and opens at 20°. S4 closes at 60° and opens at 30°. It will be observed that these degree positions correspond to boiler on-and-off points indicated on the chart, FIG. 2.

When there is a demand for heat by the temperature control, the motors MA and MB rotate until they reach a 6° position. Switch S1 closes, supplying power by way of relay SR to valve V1. Potentiometer AP1 now modulates the position of valve V1 through relay R1. Potentiometer AP1 is adjusted so that it moves through its full control range at 40° rotation of the motor shaft. Thus, if the temperature conditions are such that the control motors rotate to a 20° position, then No. 1 boiler, that is, B1, will be modulated to a half-open position, which results in slightly more than half capacity, because control potentiometer AP1 will have moved through half of its control range. At this point, boiler B1 is supplying slightly more than half of its total capacity which corresponds to 15 percent of the total capacity of all four boilers.

If the temperature controllers continue to call for additional heat, the motors MA and MB will continue rotating until they reach the 28° position. At this point switch S2 closes. This switch through relay SR now supplies power to valve V2, which now can be controlled by potentiometer AP2. Potentiometer AP2 is adjusted for the full travel over its range at 80° rotation. Thus, in the 28° position, the valve then is less than halfway open. As the first two boilers B1 and B2 are both on, they supply 30 percent of the total four-boiler capacity. This is indicated on the chart, FIG. 2.

If additional heat is required, the motors will rotate in the same direction. However, if the 30 percent total capacity is greater than the immediate demand, the No. 1 and No. 2 boilers will be putting out less capacity until at the 13 percent point, the No. 2 boiler goes off and No. 1 boiler remains on. At this point the total capacity drops suddenly from 15 percent to 10 percent.

From the foregoing, it will be understood that the system has the characteristic that it is able to modulate the capacity to conform to the load throughout the entire range of load demand. That is, as will be observed, when the second boiler is brought on it is at a little less than half capacity so that there is a step increase in boiler capacity as shown in FIG. 2. Both boilers B1 and B2 are now under modulating control. Their capacity will be modulated downwardly along the lower curve of FIG. 2 until the percent of total boiler capacity is such as to meet the load demands. Thus the effect of the step increase in capacity is compensated for by the modulating control which comes into play after the step increase. This type of operation occurs all along the load curve of FIG. 2 with the result as stated, that full modulating control of the total boiler capacity of the multiple boilers throughout the range is realized.

In like manner, the other switches bring on their respective boilers at the degree positions indicated. In all cases on an increased demand for heat at the curve follows the upward step that is created when an additional boiler is brought on. When there is a reduction in heating demand the curve follows the lower of the two curves of FIG. 2 until the point of shutting off a boiler which is accompanied by a sudden drop of capacity. The horizontal broken lines represent abrupt changes in boiler capacity.

The timing device T is set, for example, to keep switch 40 closed for 36 operating hours and then to open it for the next 36 operating hours. As described, the switch controls the two positions of the relay SR. Switch 40, as described also, controls the windings of relays R1 through R4. Assuming that switch 40 is closed and the relays are energized, then all of the switches S1 through S4 are set up to control the respective valves, V1 through V4, and these valves are controlled respectively by the potentiometers AP1, AP2, BP3, and BP4. After 36 operating hours on this sequential order of firing, the timer T opens switch 40 resulting in deenergization of all of the relays. As described in the foregoing, switch S1 is now connected to energize valve V4; switch S2 to energize valve V3; switch S3 to energize valve V2; and switch S4 to energize valve V1.

The four control potentiometers, as described, now connect to control valves V1 through V4 in reverse order, similarly. The capacity curve generated will now be the same as that shown in FIG. 2, with the exception simply that the boilers come on in the order B4, B3, B2, and then B1. In this manner, the operating hours will tend to be distributed over all the boilers more evenly.

From the foregoing, those skilled in the art will readily understand the nature and construction of the invention, its mode of operation, and the manner in which it achieves and realizes all of the objects and advantages as set forth in the foregoing. As may readily be observed, the principle of the invention is readily adaptable to other types of temperature changers, that is, devices that cool or dehumidify, as well as to heat, the control sequence being similar in such circumstances. The invention makes it possible to realize capacity curves, such as those shown in FIG. 2, both upon increasing and decreasing load, while at the same time realizing the benefits of sequencing of the units, and reverse order firing at intervals.

The foregoing disclosure is representative of a preferred form of the invention and is to be interpreted in an illustrative rather than a limiting sense.

We claim:

1. In a temperature control system having a battery of temperature-changing units, in combination, modulating means associated with each temperature-changing unit for controlling its temperature-changing capacity, temperature-responsive means including means responsive to a temperature in a region to be controlled, and means whereby said temperature-responsive means controls the modulating means of all temperature-changing units whereby to variably control the total temperature-changing capacity output of all units to correspond to temperature-changing load requirements.

2. A system as in claim 1 wherein said control means comprises means whereby to cause each temperature-changing unit to be modulatingly controlled up to a predetermined capacity at which another temperature-changing unit is caused to operate and to be modulatingly controlled.

3. A system as in claim 1 including means whereby temperature-changing units are caused to be brought into operation in sequence, each successive temperature-changing unit being modulatingly controlled up to a predetermined capacity thereof.

4. A temperature-changing system as in claim 3 including means whereby at intervals the sequence in which the temperature-changing units are brought into operation is reversed.

5. A system as in claim 4 including timing means for establishing the intervals at which the sequential order of operation of the units is reversed.

6. A system as in claim 4, including means forming part of the control means whereby each temperature-changing unit upon being brought into operation is modulatingly controlled up to a predetermined capacity at which the next succeeding temperature control unit is brought into operation.

7. A system as in claim 1, wherein said temperature control means includes a further temperature-responsive instrumentality responsive to a temperature indicative of changing load requirements.

8. A system as in claim 3 wherein the control means is constructed whereby individual temperature-changing units con-

tinue to be modulatingly controlled after the next succeeding unit is brought on.

9. A system as in claim 3 wherein the settings at which units are brought into operation are different than settings at which they are turned off.

10. A system as in claim 3, wherein the control means is constructed to bring on each temperature-changing unit at a predetermined fraction of its capacity whereby to produce a step increase in total capacity, the system being constructed to modulatingly control the units that are on to adjust the total capacity to the demands.

11. A system as in claim 10, comprising cam-operated control switches which close at individual angular positions and open at different individual angular positions.

12. A system as in claim 3, wherein the control means are constructed whereby to simultaneously modulatingly control a plurality of the multiple boilers.