

[54] **BOILER BURNER BALANCING COUNTER
CONTROL SYSTEM**

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[22] Filed: Jan. 26, 1973

[21] Appl. No.: 326,644

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 170,854, Aug. 11,
1971, abandoned.

[52] U.S. Cl. 431/12, 431/75, 431/281

[51] Int. Cl. F23n 5/00

[58] Field of Search 431/12, 48, 42, 281, 75,
431/50

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[57] **ABSTRACT**

The number of burners in operation in each of a plurality of banks of burners that are used for heating a furnace boiler are electronically counted by sensors monitoring the combustion regions of the burners and corresponding transistor circuits, the combined output of which converts the voltage of common circuits corresponding to each bank, depending upon the total number of burners actually in operation in each bank; applying the corresponding voltage outputs of the common circuits by way of an adder/subtractor amplifier to selectively programmed electronic voltage comparators, and utilizing the outputs thereof with heat load-demand requirement signals as input logic to AND-gates for continuously controlling the number of burners in operation, as well as keeping them balanced, by automatically opening and/or closing a pre-selected number of fuel supply valves to the burners depending on the programming of the comparators, to maintain the number of burners in operation in the banks equal.

11 Claims, 7 Drawing Figures

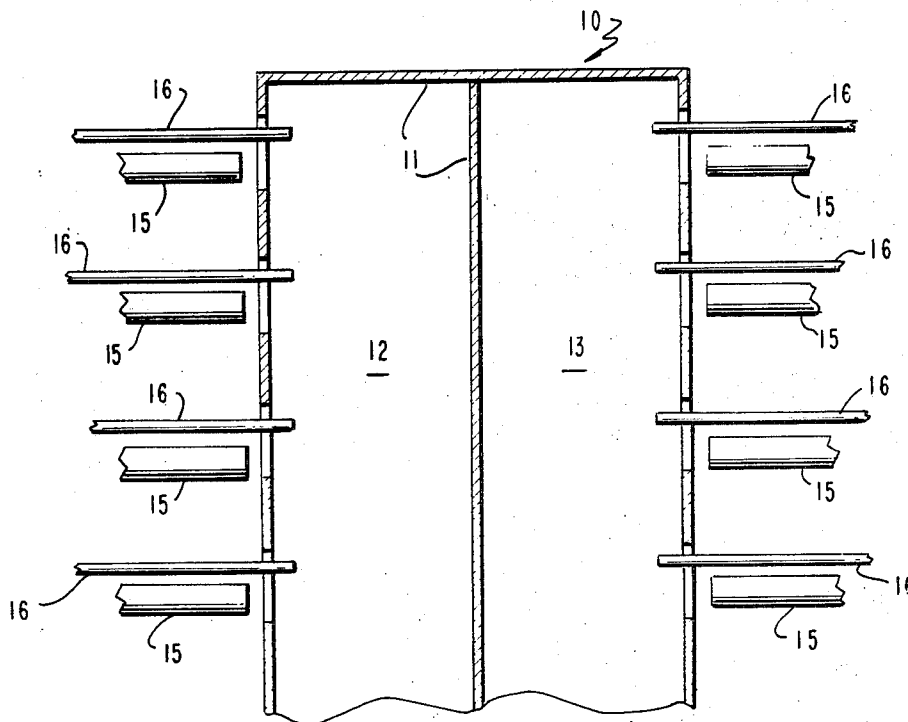


FIG. 1

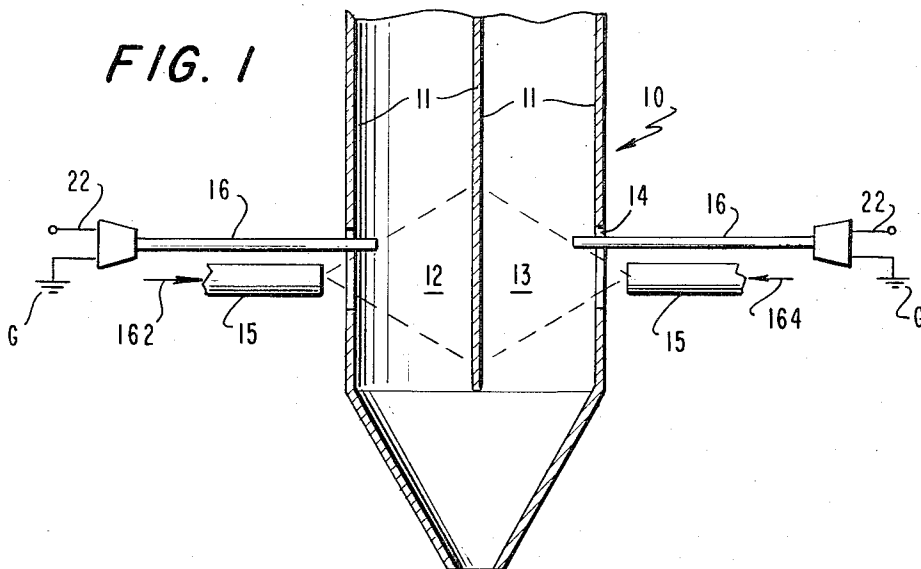
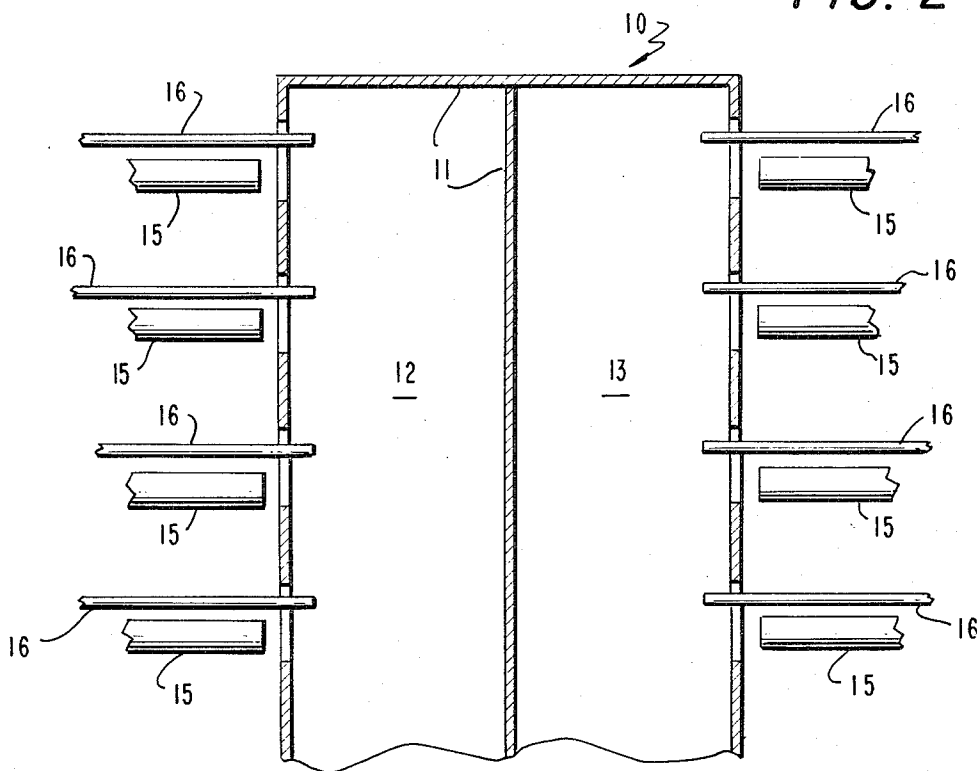


FIG. 2



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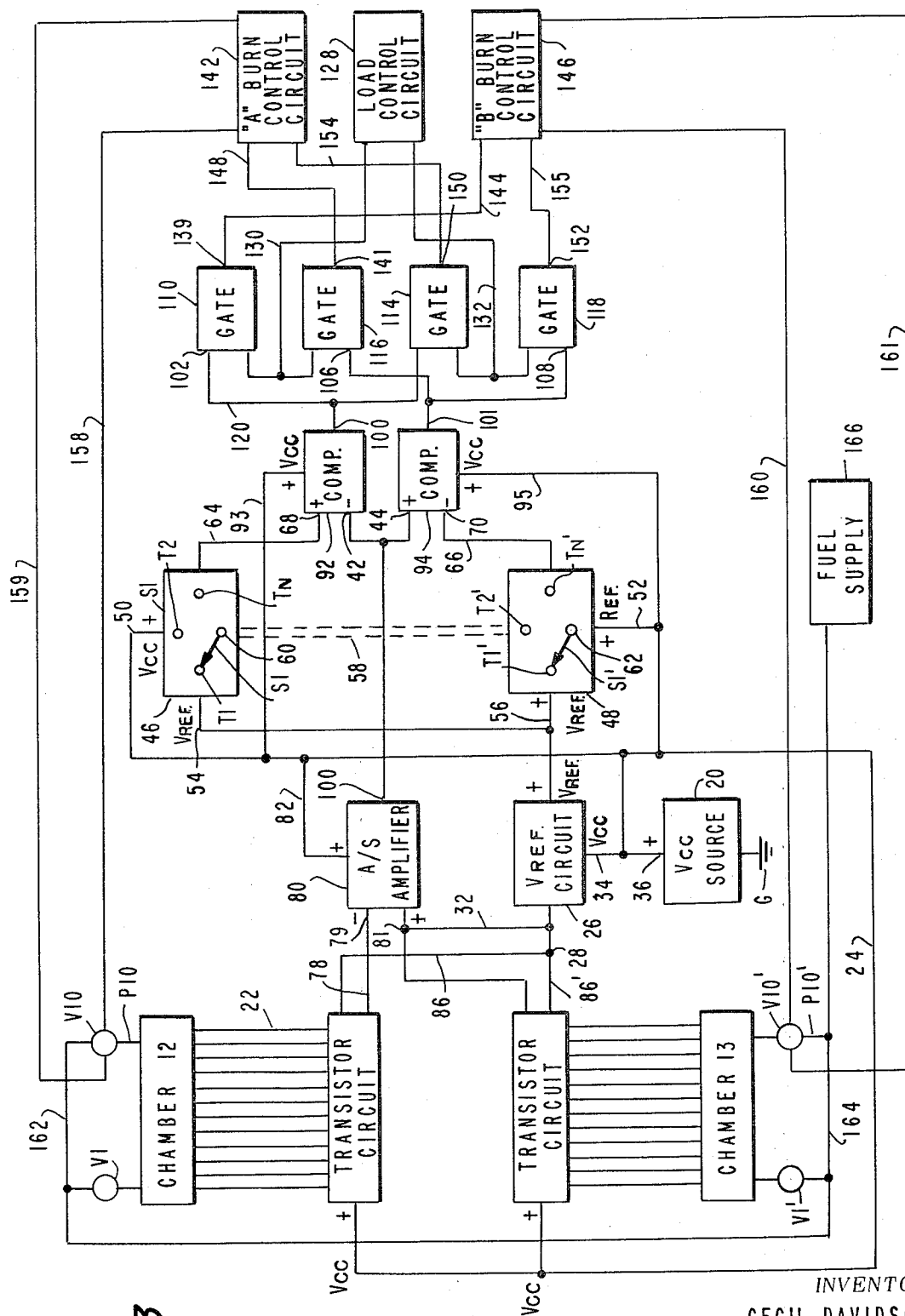


FIG. 3

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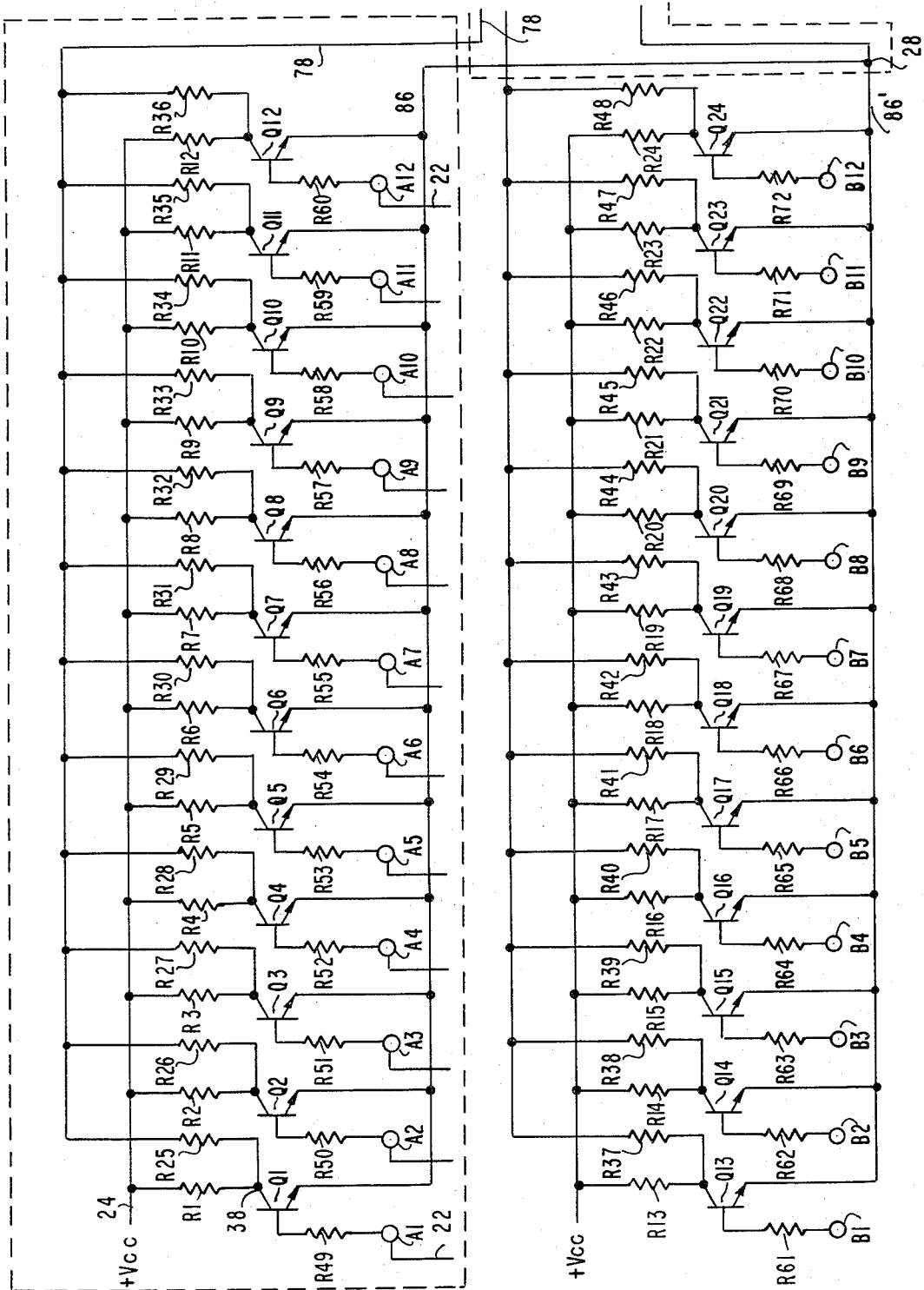


FIG. 4

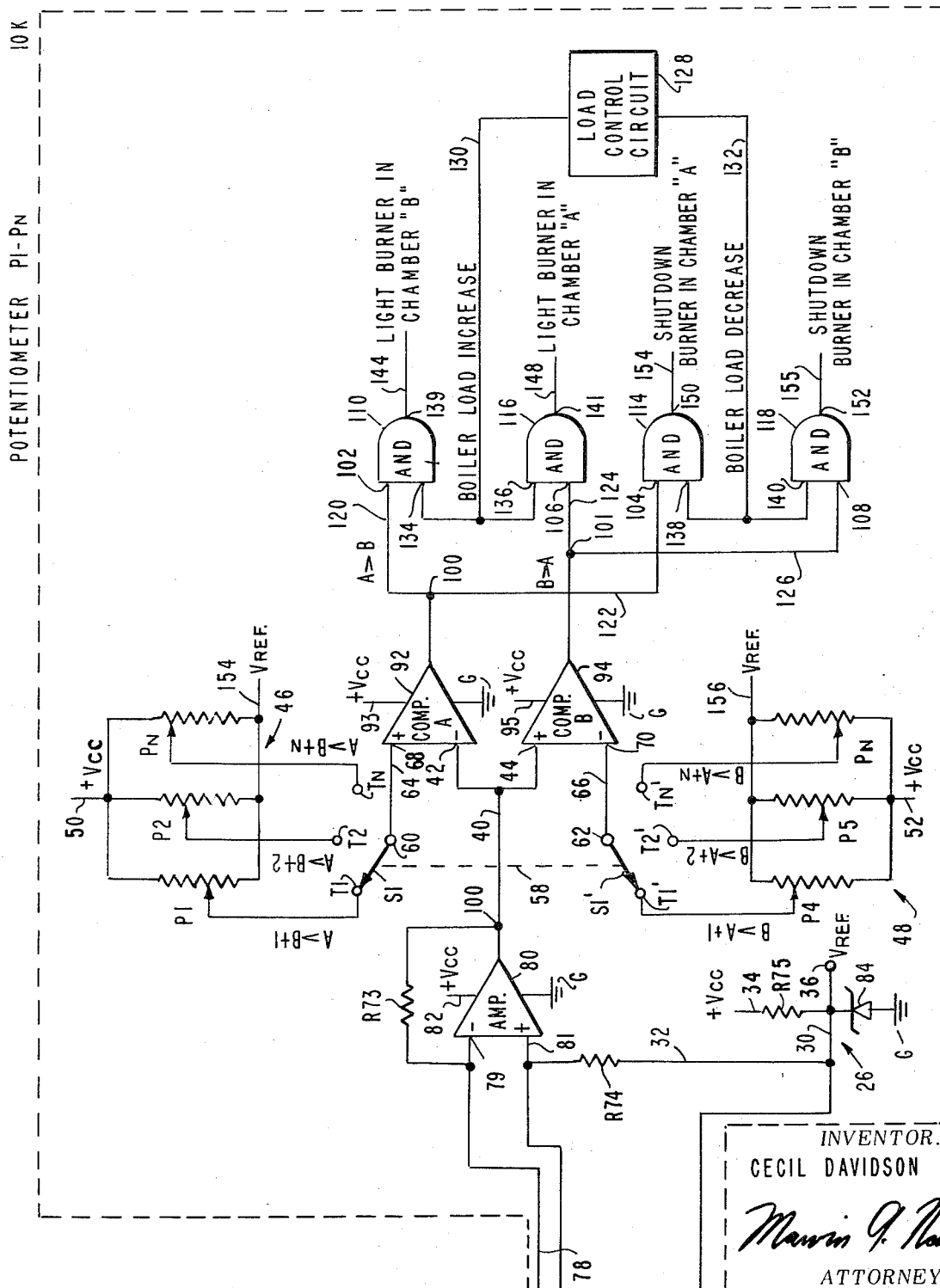
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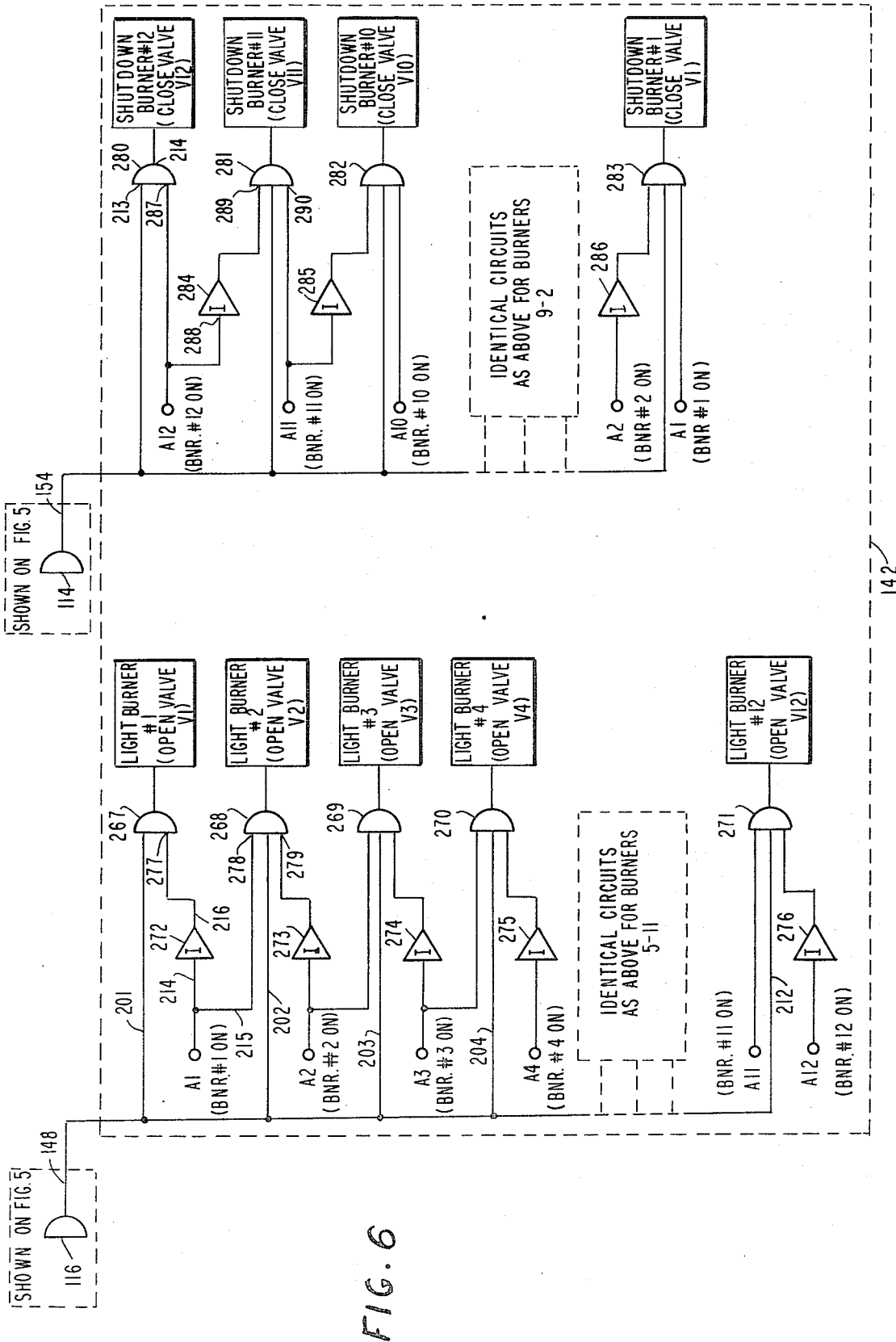
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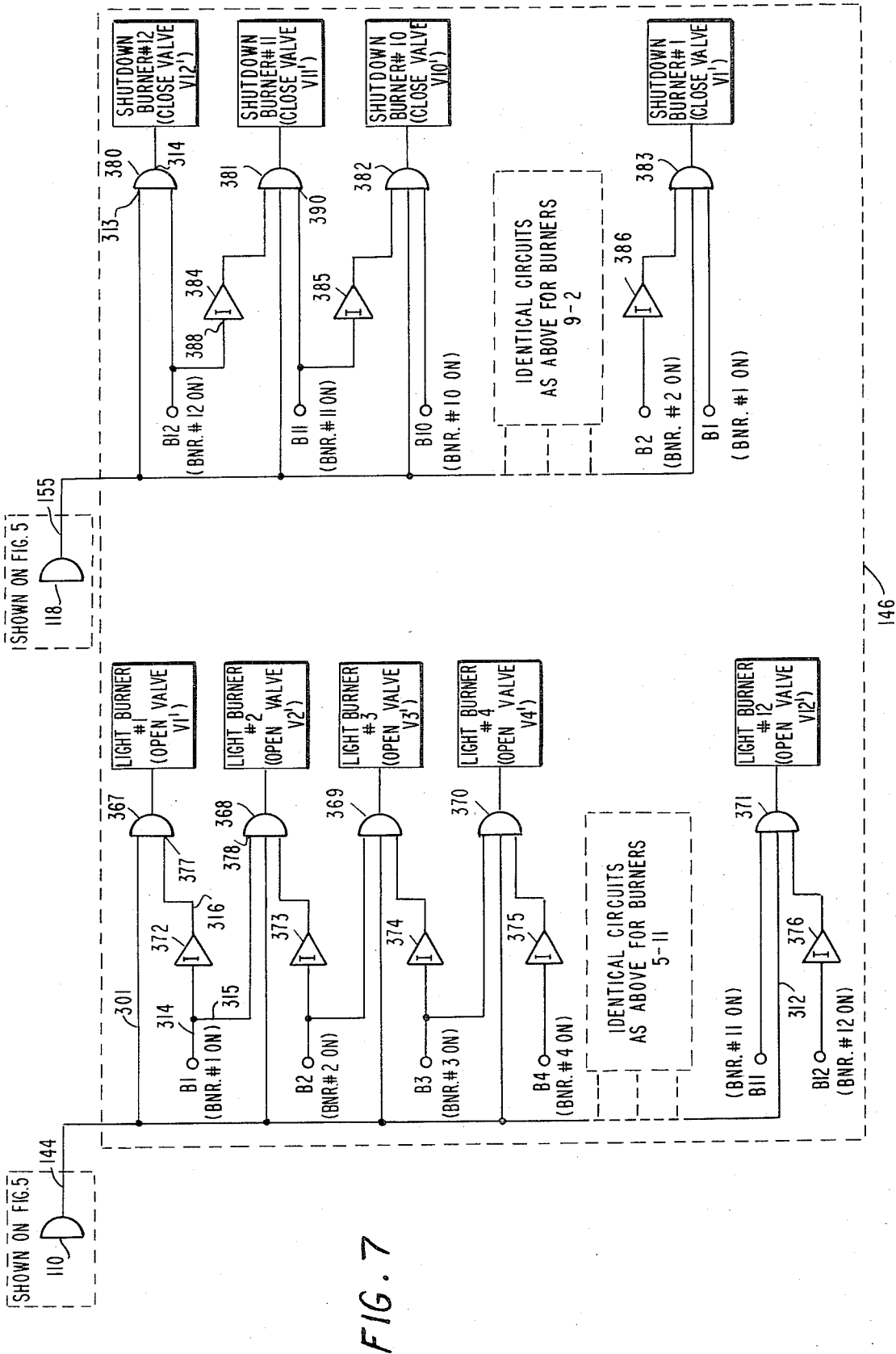
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FIG. 5







BOILER BURNER BALANCING COUNTER CONTROL SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

The present application is a continuation-in-part of applicant's copending application Ser. No. 170,854, filed on Aug. 11, 1971 and now abandoned.

BACKGROUND OF THE INVENTION

This invention relates to multi-bank multi-burner boiler furnaces, and more particularly to burner balancing-counter control systems therefor.

The invention provides a transistorized computer-like circuit for automatically counting and balancing the number of burners in operation in a plurality of different heating burner banks, such as those in separate burner chamber, or different portions of the same boiler chamber. The state of combustion, i.e. on-off conditions, of each burner is monitored continuously by a combustion sensitive device or sensor, such as a photo-cell. The circuits thereof are connected in parallel by way of N-type transistors, one for each flame detector, a voltage regulated (V_{cc}) DC supply to provide individual inputs to the corresponding transistors. The transistor output circuits are, in turn, connected in parallel across common voltage output leads, one a "collector" lead and the other an "emitter" lead. The common "collector" lead of one bank of transistors is connected to the inverting ($-$) input terminal of an amplifier circuit, and the corresponding lead of the other bank of transistors is connected to the non-inverting ($+$) terminal of the amplifier circuit. The amplifier circuit is connected in an adder/subtractor configuration, and its output varies as a function of the difference in the number of burners in service in the banks under control.

The common "emitter" leads of the transistor banks are connected to a voltage reference ($V_{Ref.}$) circuit comprising a Zener diode ground connection, and a resistance $+V_{cc}$ connection. Thus, the operation of each burner causes the corresponding sensor to forward bias the corresponding transistor, causing it to turn "ON." When a transistor is "ON," its collector is at a potential of $V_{Ref.}$, and when "OFF" at a potential of V_{cc} .

The voltage level at the inverting ($-$) input terminal of the amplifier circuit thus varies as a function of the number of burners in service in one bank, while the voltage level of the non-inverting input varies as a function of the number of burners in service in the other bank, for example. Then, as pointed out above, when the number of burners in each bank is equal, the output of the amplifier will be $V_{Ref.}$; and will increase when one (A) bank of the burners in operation is greater than the other (B); and decrease when the latter (B) is greater than the former (A).

The output of the amplifier is applied to the input terminals of electronic comparators corresponding to the burner banks. Such comparators are selectively programmed to change state when the imbalance in burners in operation in the two banks exceeds a predetermined value. The comparator outputs are transmitted to two pairs of AND-gates which also have as inputs, load-demand signal outputs from the furnace load-demand control circuit, differentially transmitted thereto when heat changes are required. The AND-

gate outputs, in turn, go to burner control circuits, one for each corresponding bank of burners under photo-cell supervision.

The system operates automatically so that the number of burners in the different heating banks is always kept equal, or balanced, either by lighting of a sufficient number of burners in both banks in case more heat is demanded, or the shutting down of burners in case less heat is required. Also, when the demand for heat is constant, the system automatically operates either to light, or shunt down, one or more burners at a time in each bank as may be required to maintain the number of burners in operation in one bank equal to those of the other bank, to satisfy the currently existing demand for heat.

In effect, the system acts automatically to constantly count the flames in each bank of burners, compare the number of flames in one bank with those in the other bank, and light, or shut off a preselected number of burners, depending upon the adjustment of the comparator programming, to keep the number of flames in the banks equal in accordance with the overall demand for heat.

The burner counter and balancing system of the invention is suitable for automatically maintaining a balance in the number of burners in service in each of two or more chambers in a multi-chambered furnace, or between the number of burners in service in different portions in the same chamber of opposed-fired boilers. The system continuously monitors the state of combustion (on-off) of the burners in each bank of two or more banks of burners in the furnace boiler unit, and automatically corrects any imbalance that tends to occur in the banks, in conjunction with current furnace heat load-demand.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a simplified diagrammatic view in vertical cross-section of a twin-chambered boiler having a bank of burners in each chamber;

FIG. 2 is a view in longitudinal cross-section thereof;

FIG. 3 is a block diagram of an embodiment of the invention for such twin-chambered boiler;

FIG. 4 is a diagram of the transistor circuit serving the bank of burners in one of the chambers;

FIG. 5 is a circuit diagram of the portion of the system that is common to both banks of burners;

FIG. 6 is a simplified circuit diagram of one chamber (A) burner control circuit; and

FIG. 7 is a similar diagram of the other chamber (B) burner control circuit.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now specifically to the drawings there is shown schematically in FIG. 1 a vapor generator furnace section 10, which is formed with heat absorption walls 11 that define dual furnace chambers 12 and 13, which are provided with port openings 14 for receiving burners 15 and flame detectors 16. Within the housing of each of the flame detectors 16, there is mounted an electronic tube for sensing ultra-violet light, together with an associated circuit, which are well known in the art and have not been shown in the drawings.

The burners 15 are arranged in opposing rows or banks, and in accordance with the specific circuit

shown in FIG. 4, it is contemplated that each of such rows will contain twelve of the burners 15. Each of the circuits within the housing of flame detector 16 is connected by one terminal to the negative side of a voltage regulated direct current source 20, FIG. 3, by way of ground G. The other terminal of the circuits within the housing of flame detector 16 is connected by lead 22 to a corresponding input terminal A1-A12, FIG. 4, of an N-type transistor Q1-Q12, respectively. The transistor junctions (collectors) 38 are connected through resistors R1-R12 to the positive (+Vcc) side of the DC source 20, FIG. 3, by a circuit 24, and through resistors R25-R36, FIG. 4, to a circuit 78 which is, in turn, connected to the inverting (-) terminal 79, FIG. 5, of an amplifier 80. The amplifier is provided with a negative ground connection G and a positive DC source voltage (Vcc) lead 82 connected to the circuit 24, FIG. 3.

A V Ref. circuit 26, FIG. 5, contains a resistor R75, and is connected to ground G by way of a Zener diode 84. The output circuits of transistors Q1-Q12, FIG. 4, are connected in parallel with one another across circuits 78 and 86, FIG. 5. The circuit 86, FIG. 3, is connected to the corresponding circuit 86' at juncture 28 from which lead 30, FIG. 5, connects to circuit 26 and lead 32 connects through resistor R74 to the noninverting (+) input 81 of amplifier 80. The circuit 26 is connected to the Vcc source 20, FIG. 3, by a lead 34 containing the resistor R75, FIG. 5, and provides a (+) source of reference voltage (V Ref.) at terminal 36.

Thus, with the corresponding burner, for example, in service, the input at A1, FIG. 4, will be a one ("1") logic level and will forward-bias transistor Q1, causing it to turn "ON." When transistor Q1 is "ON," its collector 38 will be at a potential of V. Ref., and when "OFF," at a potential of Vcc.

The voltage level at the inverting (-) input terminal 79 of the amplifier 80, FIG. 5, varies as a function of the number A of burners in service in chamber 12. Likewise, the voltage level at the non-inverting (+) input terminal 81 of the amplifier 80 will vary as a function of the number B of burners that are in service in chamber 13.

The amplifier comprises a feedback resistor R73, FIG. 5, connected across (-) input terminal 79 and output terminal 100, and resistor R74 connected across the positive input terminal of V. Ref., circuit 26; and is connected in an adder/subtractor configuration, so that its output voltage will vary as a function of the difference in number ($A \pm B$) of burners in service in chambers 12 and 13. When the number of burners in service in each chamber is equal, ($A=B$), the output potential of the amplifier 80 will be V Ref., and will increase when the burners B in service in chamber 13 are greater than those A in service in chamber 12, i.e., $B > A$. Similarly, when $A > B$, the output potential of the amplifier 80 will decrease.

The output terminal 100, FIG. 5, of the amplifier 80 is connected by lead 40 to the (-) and (+) input terminals 42 and 44, respectively, of comparators 92 and 94. The output terminals 100, 101 of comparators 92 and 94 are, in turn, connected to input terminals 102, 104 and 106, 108, respectively, of AND-gates 110, 114 and 116, 118 by leads 120, 122 and 124, 126. A furnace load-demand control circuit 128 is provided with differential heat demand leads 130 and 132, connected to input terminals 134 and 136 of gates 110 and 116, and input terminals 138 and 140 of gates 114 and 118.

The comparators 92 and 94 are provided with programming circuits 46 and 48, FIG. 5, comprising in each case a plurality, three for example, of potentiometers P1, P2, Pn, and P4, P5, Pn, respectively. The potentiometers have Vcc potential input leads 50, 52 that are connected to the DC (Vcc) source 20, FIG. 3, and V Ref. potential input leads 54, 56 that are connected to the reference voltage (V Ref.) circuit 26. Each programming circuit 46, 48 also is provided with three switch taps T1, T2, Tn and T1', T2', Tn', respectively. The taps are arranged to be contacted by adjustment of switch arms S1 and S2 that are mechanically connected by a link 58, so that when one contact of one circuit is selectively contacted, the corresponding tap of the other circuit is also contacted. The switch arms S1 and S2 have fixed terminals 60 and 62, that are connected by leads 64 and 66 respectively, to the non-inverting (+) input terminal 68 and the inverting (-) input terminal 70 of the comparators 92 and 94.

The comparators are provided +Vcc leads 93 and 95, respectively, FIG. 3, as well as with ground connections G, FIG. 5.

The comparators 92 and 94 are selectively programmed depending upon the tap setting of switches S1 and S1', to change state when an imbalance in the number ($A \pm B$) of burners in service in the two chambers 12 and 13 exceeds a predetermined value (number).

The output terminals 139, 141 of gates 110 and 116, FIG. 3, are connected to input terminals of "B" and "A" burner control circuits 146 and 142, by leads 144 and 148, respectively. Similarly, the output terminals 150 and 152 of gates 114 and 118 are connected to such control circuits 142 and 146 by leads 154 and 155, respectively. The output circuits 158, 159 of the "A" burner control circuit 142, and 160, 161 of the "B" burner control circuit 146 are connected to solenoid type fuel control valves V10 and V10', respectively, for opening and closing individual fuel supply pipes P10 and P10' to the burners 15, FIG. 1, as may be required by the operation of the system. There is a fuel supply pipe for each burner, FIG. 1, and the pipes P10, FIG. 3, to the burners 15 in chamber 12, FIG. 1, are connected to a fuel supply conduit 162, FIG. 3, while those to chamber 13, FIG. 1 are connected to a fuel supply conduit 164 via pipes P10'. The conduits 162, 164 are, in turn, connected to a suitable pressurized fuel supply source 166, FIG. 3.

In operation, assuming that the first burner 15, FIG. 2, is in operation in chamber 12, the input at terminal A1, FIG. 4, will be a one (1) logic level, and will forward-bias transistor Q1, causing it to turn "ON." When transistor Q1 is "ON," its collector 38, will be at a potential of V Ref., and when "OFF" at a potential Vcc. The total voltage level at the inverting (-) input terminal 79, FIG. 3, to adder/subtractor amplifier 80 will thus vary as a function of the number A of burners 15 that are in service in the bank in chamber 12, FIG. 2. Also, the voltage level at the non-inverting (+) input terminal 81, FIG. 3, to amplifier 80 will also vary as a function of the number B of burners 15, FIG. 2 that are in service in the bank in chamber 13.

When the number ($A \pm B$) Of burners in service in each of the banks in chambers 12 and 13, FIG. 2 is equal, the output voltage at terminal 100 of the amplifier 80, FIG. 3, equals V Ref., and increases when the number B of burners in operation in chamber 13 is greater than the number A of burners in operation in

chamber 12, i.e., $B > A$. Similarly, such output voltage decreases when $A < B$. The output of the amplifier 80 is applied to the inputs of the comparators 90 and 94.

The comparators 90 and 94, FIG. 5, are programmed as desired by adjusting switches S1 and S1' to change state when unbalance in the number of burners in operation in the chambers 12 and 13, FIG. 2, exceeds the preselected value. For example, assuming that switches S1 and S1', FIG. 5, are set in mid-position in contact with taps T2 and T2', potentiometers P2 and P5 are adjusted so that the comparators will change state when the unbalance between numbers A and B exceeds two, i.e., either count $A > B+2$, or $B > A+2$.

When $A > B+2$ the output of comparator 92 is logic one ("1"); and when $B > A+2$, the output of comparator 94 is a logic one ("1").

The outputs from the two comparators 92 and 94 are then used in conjunction with boiler load-demand signals from the load control circuit 128 by the AND-gates 110, 114, 116 and 118, and "A" and "B" burner control circuits 142 and 146 to determine when and in which of the banks of chambers 12 and 13, FIG. 2, the required burners 15 are placed in, or removed from service.

The "A" and "B" burner control circuits 142 and 146 of FIG. 3, for chambers 12 and 13 respectively are shown in FIGS. 6 and 7.

Referring to FIG. 6, if there is an increase in boiler load as determined by the boiler balancing counter, then the A burners must be placed in service. A signal to light the A burners in chamber 12 is applied through circuit 148 and branches 201, 202, 203, 204 and 212 to corresponding inputs on AND-gates 267, 268, 269, 270 and 271. As pointed out above, the output of the flame detectors are connected to terminals A1 through A12. The signal from terminal A1 is applied through lead 215 to the input of an inverting amplifier 172, and also via lead 215 to the input 278 on AND-gate 268.

The output of inverting amplifier 272 is connected by lead 216 to input 277 of AND-gate 267. With a burner lighting demand signal on circuit 148 from AND-gate 116 being present, and burner No. 1 out of service, the input at inverting amplifier 272 will be a zero (0) logic level, and the output of inverting amplifier 272 will be a logic one (1). With logic ones (1) at both inputs of AND-gate 267, the output will be a logic one (1), thus causing burner No. 1 to be placed in service.

If burner No. 1 is in service, then the input 278 at AND-gate 268 will be a logic one (1), and if burner No. 2 is out of service, the input to inverting amplifier 272 will be a logic zero (0). This results in a logic one (1) at input 279 on the AND-gate 268 command signal, thereby causing the burners in chamber A to light and all three inputs to AND-gate 268 provide a logic one (1) level, thus causing a logic one (1) on its output, lighting burner No. 2. Such procedure is repeated until the correct number of burners is placed in service to satisfy the boiler load demand at which time the output of AND-gate 116 will switch to a logic zero (0) level and no more burners will be placed in service.

Assuming all 12 burners are in service, the burner shut-down operation is as follows:

With a signal on circuit 154 calling for shutdown of the A burners in chamber 12 from the output of AND-gate 114, with burner No. 12 in service, a logic one (1) will be present at both inputs 213, 287 to AND-gate

280, causing a logic one (1) at its output 214 which will shut down burner No. 12 by closing valve V12. If burner No. 12 is not in service, the signal from terminal A12 will be a zero (0) which is applied to inverting amplifier 284, causing its output to be a logic one (1) which is applied to input 289 of AND-gate 281.

If burner No. 11 is in service, the output from terminal A 11 will be a logic one (1) which is applied to input 290 of AND-gate 281. If the command signal on circuit 154 to shut down burners in chamber A is still present, then all three inputs to AND-gate 281 will be a logic one (1), thus providing a logic one (1) on its output, causing burner No. 11 to shut down. Such procedure is repeated until the proper number of burners is shut down to satisfy the boiler load demand.

In FIG. 7 there is illustrated a further embodiment of the invention in which corresponding parts have been designated by the same reference numerals as part of a "300" series. Referring to circuit 146 of FIG. 7, if there is an increase in boiler load as determined by the boiler balancing counter, the B burners must be placed in service. A signal to light the B burners in chamber B is applied through circuit 144 and branches 301, 302, 303, 304 and 312 to corresponding inputs on AND-gates 367, 368, 369, 370 and 371. As pointed out above, the output of the flame detectors are connected to terminals B1 through B12. The signal from terminal B1 is applied through lead 314 to the input of an inverting amplifier 372, and also via lead 315 to the input 378 on AND-gate 368.

The output of inverting amplifier 372 is connected by lead 316 to input 377 of AND-gate 367. With a burner lighting demand signal on circuit 144 from AND-gate 110 being present, and burner No. 1 out of service, the input at inverting amplifier 372 will be a zero (0) logic level, and the output of inverting amplifier 372 will be a logic one (1). With logic ones (1) at both inputs of AND-gate 367, the output will be a logic one (1), thus causing burner No. 1 to be placed in service.

If burner No. 1 is in service, then the input 378 at AND-gate 368 will be a logic one (1), and if burner No. 2 is out of service, the input to inverting amplifier 373 will be a logic zero (0). This results in a logic one (1) at input 379 on the AND-gate 368 command signal, thereby causing the burners in chamber A to light, and all three inputs to AND-gate 368 provide a logic one (1) level, thus causing a logic one (1) on its output, lighting burner No. 2. Such procedure is repeated until the correct number of burners is placed in service to satisfy the boiler load demand at which time the output of AND-gate 110 will switch to a logic zero (0) level and no more burners will be placed in service.

Assuming all 12 burners are in service, the burner shut-down operation is as follows:

With a signal on circuit 155 calling for shutdown of the B burners in chamber 13 from the output of AND-gate 118, with burner No. 12 in service, a logic one (1) will be present at both inputs 313, 387 to AND-gate 380, causing a logic one (1) at its output 214 which will shut down burner No. 12 by closing valve V12'. If burner No. 12 is not in service, the signal from terminal B12 will be a zero (0) which is applied to inverting amplifier 384, causing its output to be a logic one (1) which is applied to input 389 of AND-gate 381.

If burner No. 11 is in service, the output from terminal A 11 will be a logic one (1) which is applied to input 390 of AND-gate 381. If the command signal on

circuit 155 to shut down burner in chamber A is still present, then all three inputs to AND-gate 381 will be a logic one (1), thus providing a logic one (1) on its output, causing burner No. 11 to shut down. Such procedure is repeated until the proper number of burners is shut down to satisfy the boiler load demand. 5

Thus, the system continuously monitors the operation of the burners in chambers 12 and 13 by counting and comparing them, and produces a balancing output when any unbalance occurs between the chambers, thereby maintaining the number of burners in operation in the banks equal in accordance with the currently existing demand for heat required in the furnace. 10

A latitude of modification, change and substitution is intended in the foregoing disclosure and in some instances some features of the invention will be employed without a corresponding use of other features. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the spirit and scope of the invention herein. 20

I claim:

1. A multi-bank multi-burner furnace boiler burner balancing control system comprising:

separate electronic circuits for counting the number of burners in operation in each bank of burners, an additive/subtractive amplifier circuit connected to said burner counting circuits, electronic comparator circuit means responsive to said amplifier circuit for comparing the actual number of burners in operation in one bank with another, 30

AND-gate circuit means for utilizing the outputs of said comparator circuit means as logic to produce output signals responsive to a difference in the number of burners in operation in one bank with respect to another, and 35

control circuit means responsive to such output signals for operating said burners, to keep the number of burners in operation in said banks equal to one another. 40

2. The invention as defined by claim 1, in which the burner banks under control are located in opposite portions of a common chamber.

3. The invention as defined by claim 1, in which the burner banks under control are located in different chambers of a multi-chambered furnace. 45

4. The invention as defined by claim 1, in which each of the electronic flame counting circuits comprises 50

flame detector means for sensing the "ON" - "OFF" state of each burner by "looking" continuously at the region of combustion thereof;

an individual transistor having an input circuit responsive to the activation of the corresponding flame detector means, and an output circuit; 55

a common counting circuit for each bank of burners, across which the transistor output circuits thereof are connected in parallel, and are, in turn, connected to the amplifier circuit means. 60

5. The invention as defined by claim 4, in which the electronic comparator circuit means are responsive to digital voltage changes in said counting circuits corresponding another a selected number in each bank, whereby when one bank contains more or less burners in operation than in another bank, corresponding correctional signals are applied to 65

said AND-gate circuit means to bring the burners in operation into balance.

6. The invention as defined by claim 5, in which said electronic comparator circuit means comprises comparators corresponding in number to the number of burner banks in operation, and

said AND-gate circuit means comprises two AND-gates for each comparator, and

a load-demand control circuit is provided having output connections serving as differential load-demand inputs to said AND-gates for controlling the number of burners in operation in the banks to maintain the demand for heat.

7. The invention as defined by claim 6, in which the bank-burner control circuits are controlled by the outputs of said AND-gates for turning such burners "OFF" and "ON" as may be required, and individual fuel supply pipes for each burner are provided having a solenoid-valve therein that is operated by the corresponding bank-burner control circuit to open and close said solenoid-valve and thereby turn the corresponding burner "ON" and "OFF."

8. Method of continuously balancing the number of burners in operation in a multi-bank of multi-burners in furnace boiler, which comprises:

continuously electronically counting the number of burners in operation in each bank by continuously inspecting the region of combustion of each burner with a suitable sensor,

deriving a voltage signal the logic of which is a function of the number of burners in operation in each bank by virtue of the operation of each burner being sensed,

electronically comparing the resulting voltage logic signals of the burner banks by applying such signals to voltage comparators equal in number to the burner banks to thereby produce output signals responsive to a difference in the number of burners in operations in the several banks, and

using such output signals to correct any imbalance between the banks by automatically shutting-off and turning-on a selected number of burners in the proper bank to bring them back into equalization with the other bank as may be required by the load-demand on the furnace.

9. A multi-burner flame balancing system for selectively controlling the on-off operation of fuel burners in different heating zones under a boiler so as to automatically equalize the number of burners in operation in such zones, comprising:

flame sensitive means responsive to the operation of each of the burners in service in the different zones,

an individual transistor input circuit connected to each flame sensitive means,

a common constant voltage supply circuit for all of said flame-sensitive-input to circuits,

a common voltage output circuit for the transistors of each of said zones,

an additive/subtractive amplifier connected to such output circuit,

a voltage reference circuit connected to said output circuit and said constant voltage supply circuit, voltage comparator circuits connected to the output terminal of said amplifier,

AND-gates operatively connected to said comparator circuits,
means including valves for supplying fuel to said burners, and
valve control circuit means for operating said valves, 5
whereby,
when a signal is received calling for a change in the heat provided by the burners to the boiler, valves are operated so that the burners in operation in the different zones are kept in balance (equal). 10
10. The invention as defined by claim 9, in which means are provided for programming the comparators whereby the number of burners in each bank under the control of the logic of the amplifier is adjustable for preselecting such number from one to 15

two and up.
11. The invention as defined by claim 10, in which said comparator programming means comprises a plurality of potentiometers associated with the inputs of each comparator,
corresponding switch tapes connected to each potentiometer,
switch arms having a fixed terminal connected to the opposite (+ and -) input terminals of said comparators, and
a link connecting said switch arms for adjustment in unison to corresponding taps of said program means.

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