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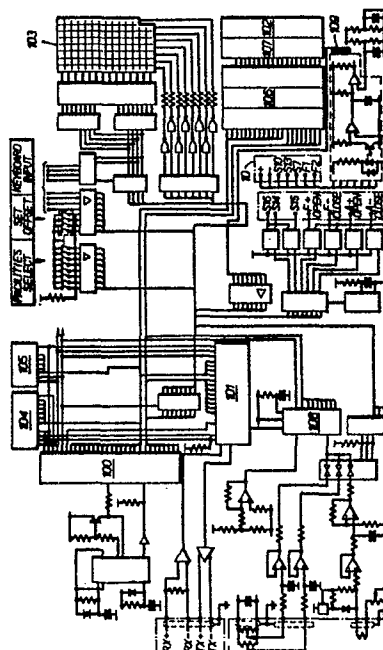
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54 **Improvements in or relating to fuel burner control systems.**

57 A fuel burner control system includes a memory and processor means, operable in a commissioning mode under the control of the processor means, in cooperation with operator controlled means, to effect the generation of output values for setting a fuel valve and an air valve and to effect the entry of values for fuel valve and air valve settings into the memory, and operable in a run mode to provide, in response to each of a plurality of input signal values representative of respective values of a first variable, the appropriate stored values for fuel valve and air valve settings.



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"Improvements in or relating to fuel burner control systems"

The invention relates to a fuel burner control system capable of controlling the supply of air and fuel to a burner, and to a combustion process control system including such a fuel burner control system.

5 The quantity of air and fuel supplied to a fuel burner should be controlled in such a manner that the fuel is burned completely without having a significant quantity of excess air. The supply of too little air results in incomplete combustion and the waste of fuel whilst the supply of too much
10 air results in the absorption of some heat by the excess air. For efficient combustion the ratio of the quantity of the fuel supplied to the burner to the quantity of air supplied to the burner should be constant at a value which provides just enough oxygen for complete combustion to take place. However, because
15 of the behaviour of the fuel and the air flowing through the respective control valves, the ratio of the extent of opening of the fuel valve to the extent of opening of the air valve to provide a constant fuel : air ratio is not constant over the heat supply range of the burner.

20 Burner control systems are known to employ mechanically linked air and fuel supply valves in order to achieve the

desired constant fuel: air ratio over the heat range of the burner but, in general, adjustment by mechanical linkage achieves efficient combustion of fuel over a small part only of the burner heat supply range.

5 Also, burner control systems are known to employ computers for controlling air and fuel supply valves, a computer linked to a heat demand control and a flue gas sensor, or flue gas sensors, being programmed to effect adjustment of the valves to provide the desired heat demand
10 at a programmed signal from the flue gas sensor or programmed signals from the flue gas sensors.

 Additionally, burner control systems are known to employ computers for commissioning, during which the air and fuel supply valves are set by means of a computer in accordance
15 with heat demand inputs and programmed flue gas sensor signals, and the valve settings at respective heat demand inputs stored by the computer. The stored data on valve settings is later transferred from the computer to a resident memory belonging to the burner control system.

20 In both fully automatic computerised systems and computer assisted automatic commissioning systems, there is a cost penalty for the programming of the computer.


 The present invention provides a burner control system capable of achieving significant improvements in performance
25 over known mechanically linked systems at costs significantly below those associated with fully automatic computerised systems,

or computer assisted commissioning systems.

In accordance with the present invention, a control system for a fuel burner has a commissioning mode and a run mode and comprises a fuel valve and an air valve, a
5 memory holding values of air valve and fuel valve settings and a processor operable, in the run mode, to provide, from the memory and in response to each of a plurality of input signal values representing values of a first variable, respective values for air valve and fuel valve settings
10 wherein the processor is operable, in the commissioning mode, to effect entry into the memory of the said values of air valve and fuel valve settings and wherein each of those values is derived from an operator selection of the settings of at least one of the valves.

15 The present invention also provides a fuel burner control system, including a memory and processor means, operable in a commissioning mode under the control of the processor means, in cooperation with operator controlled means, to effect the generation of output values for setting a fuel
20 valve and an air valve and to effect the entry of values for fuel valve settings and corresponding air valve settings into the memory, and operable in a run mode to provide, in response to each of a plurality of input signal values representative of respective values of a first variable, the appropriate
25 stored values for fuel valve and air valve settings.

In control systems in accordance with the present invention,



flexibility in the complex relationship between the valve settings is achieved by the use of a memory for storing valve setting values, and simplicity in commissioning is achieved by providing for operator involvement in the
5 commissioning operation. In particular, an operator using flue gas analysis equipment is involved in the commissioning mode to ensure that the valve setting values used at each heat demand input result in ideal, or very close to ideal, combustion conditions, the processor being operative during
10 the commissioning phase to permit control of the valves, by way of operator controls, and the entry of valve setting data into a memory on command from the operator. The result is a highly accurate control system at a cost well below that of systems employing automatic control or automatic commissioning.

15 Advantageously, the processor is capable of determining a setting value for one valve for each value of the first variable, and is arranged to select increasing setting values for the valve with increasing values of the first variable over a limited range of values of the first variable, and
20 outside the limited range, to select a fixed setting value for the valve, and preferably, the limited range of values of the first variable lies between five and twenty percent of the possible range of the first variable.

Additionally, the processor may include means for adjust-
25 ing the limits of the limited range of values of the first variable.

Advantageously, the memory is so organised that the address of each fuel valve setting value points to the address of the corresponding air valve setting value, or vice-versa.

5 Advantageously, the control system includes data as to the number of valve settings the memory is intended to accommodate and is capable of operating in a run mode only when all the air and fuel valve settings are present in the memory, and preferably, the memory holds data as to the open
10 and shut positions of the valves.

Advantageously, the first variable is the difference between second and third variables, and, preferably, the second and third variables are the actual and desired operating temperatures, respectively, of a medium arranged
15 to be heated by a burner controllable by the control system.

Additionally, the control system may include display means and be capable of displaying the second and third variables alternately on common display elements.

A boiler installation may, of course, include a control
20 system in accordance with the present invention.

A burner control system in accordance with the present invention and a combustion process control system including the burner control system will now be described by way of example only and with reference to the accompanying drawings, in which :-

- Fig. 1 is a schematic representation of a combustion process control system arranged as the central unit of an electrical system capable of controlling a boiler,
- 10 Fig. 2 is a block schematic representation of the combustion process control system of Fig. 1,
- Fig. 3 is an illustration of a control panel of the combustion process control system of Fig. 1,
- Fig. 4 is a flow chart representation of the operation of the combustion process control system of Figs. 1 and 2,
- 15 Fig. 5 is a graphical representation of the relationship between the fuel valve setting and, (i) the deviation of the actual temperature from the thermostat setting (the upper abscissa scale), and, (ii) the temperature relative to the thermostat setting $T^{\circ}C$ (the lower abscissa scale), for a burner control system according to the invention, and,
- 20 Fig. 6 is a diagrammatic representation of the arrangement of fuel and air valve setting
- 25

data in an addressable data store, for a burner control system according to the invention.

Referring to Fig. 1, an electrical system capable of controlling a boiler includes a combustion process control system 1, an air supply control valve 2, a fuel supply control valve 3, an air control valve motor 4, a fuel control valve motor 5, position indicating potentiometers 6 and 7, a thermostat 8, and a fuel selector switch 9. The combustion process control system 1 includes a plurality of input ports by means of which it receives information from its sensors and output ports by means of which it provides information to actuators and the like. The combustion process control system 1 includes input ports F1, F2 one of which is energised by means of the fuel selector switch 9 to signal the type of fuel in use, a temperature sensor input port T1/T2 for receiving information as to an actual temperature, a remote load control input port 10 for receiving information as to a desired temperature, a boiler thermostat input port S10, an open / start switch position-sensing input port S13, switch position-sensing ports S14 and S15, a load control switch sensing port S7, an air valve position sensing input port A, and a fuel valve position sensing port F. Also included are output ports A+ and A- for controlling the air control valve motor 4 and output ports F+ and F- for controlling the fuel valve control

motor 5.

Referring to Fig. 2, the combustion process control system 1, of Fig. 1, includes a microprocessor 100, a serial timer interrupt controller 101, an electrically erasable memory 102, a plurality of displays 103, input/output controllers 104 and 105, a fixed programme memory 106, a random access memory 107, and an analogue-to-digital converter 108. The microprocessor is a Type Z80 integrated circuit which, under the direction of the fixed programme memory 106, reads the signals at the various input ports and executes the actions for providing control signals at the appropriate output ports in addition to providing information for the displays 103. The serial timer interrupt controller 101, which is a Type MK 3801 integrated circuit, is a multi-function device providing a USART (Universal Synchronous/Asynchronous Receiver/Transmitter), four timers (two binary and two full function), and eight bidirectional input/output lines with individually programmable interrupts. The random access memory 107 acts as a short term store for the signals received from input ports and the signals to be presented to output ports. The random access memory 107 acts also as a scratchpad memory for the microprocessor 100. The input/output 104 and 105 control the activation and deactivation of the ports as instructed by the microprocessor 100 and the serial timer interrupt controller 101. The signals from

the temperature sensor port (T1 - T2) and the valve motor position indicator ports (F, A) are subjected to analogue-to-digital conversion by the analogue-to-digital converter 108. The signals from the remote
5 load sensing port 10 and other ports in its group (S7, S10, S13, F1, F2) are each subject to modification by means of a level-translating circuit 109 which also provides electrical isolation by means of optical
10 coupling. There are provided manual controls capable of effecting the operations listed below. The manual controls are identified on the front panel represented in Fig. 3.. The manual controls are switches connected to a plurality of control input ports shown in Fig. 2.

The operations referred to above are :-

- 15 1. Placing the combustion process control system in either the commissioning mode or the run mode, and, in the commissioning mode :-
2. Increasing or decreasing the fuel supply.
3. Increasing or decreasing the air supply.
- 20 4. Increasing or decreasing the desired temperature.
5. Signalling to the system the positions of the air and fuel valves relative to their respective open and closed positions.

25 Referring to Fig. 4, the operations carried out by the combustion process control system commence with switch-on and the selection of fuel (1). The system then checks whether or not it has a look-up memory with information for the fuel selected (2) and, if not,

places itself in the commissioning mode permitting control by means of the manual controls shown in Fig. 3 and illuminating the CLOSE POSITION and ENTER MEMORY displays at the control panel (3). The manual controls
5 for the air and fuel valve motors are then used by the operator to close both valves (indications of the positions of the valves are given at the control panel) and the operator presses ENTER MEMORY on the front panel when he is satisfied that the valves are closed
10 (4). The system then illuminates a SET STAT display, indicating that the operator should enter a temperature setting at which the burner is to be extinguished in order to prevent a further rise in the temperature of the medium being heated e.g. water in a boiler. The
15 OPEN POSITION and ENTER MEMORY displays on the control panel are next illuminated (7) and the operator uses the manual controls to open both valves fully and presses ENTER MEMORY on the first panel when he is satisfied that both valves are open (8). The system next purges
20 waste gases from the combustion chamber (9) after which it illuminates the START POSITION display on the control panel (10, 11, 12). The manual controls are then used by the operator to open partially both valves to allow ignition and combustion of fuel and he then presses
25 START POSITION (13) to initiate boiler operation. The system then illuminates the HIGH POSITION and ENTER MEMORY displays on the front panel (14). The manual

controls are used by the operator to obtain, from the burner, a maximum heat output suitable for the installation in which it is being used while ensuring efficient combustion at the maximum heat demand (15). This part
5 of the operation is executed with the aid of combustion analysis equipment and requires an operator skilled in the use of such equipment. When the operator is satisfied that efficient combustion is taking place at the high heat demand setting he presses ENTER MEMORY (15).
10 The system then decides whether subsequent operation is to be for the entry of intermediate or start data (17), and, for the entry of intermediate data, illuminates the INTER POSITION and START displays on the front panels (16). For the entry of intermediate data, the operator
15 presses INTER (18), selects some fuel valve setting below the maximum value set previously, adjusts the air valve to provide efficient combustion at this new intermediate heat demand setting, and when he is satisfied that the combustion is efficient he presses ENTER
20 MEMORY (19). The system continues to illuminate the INTER and START displays (return to 16) until the required number of locations in the look-up memory are filled with values for intermediate fuel valve and air valve settings. On completion of the entries for
25 intermediate settings the START and ENTER MEMORY displays are illuminated (20), the operator uses the manual controls to set a selected START position for the fuel valve, adjusts the air valve for efficient combustion

and then presses the ENTER MEMORY display/switch to effect entry of the settings into the memory (21). The system then illuminates the RUN display on the front panel to indicate that it is ready for operation
5 (22) which is effected by pressing RUN (23).

When the RUN control is operated at the end of the commissioning phase the combustion process control system deactivates all of the front panel controls with the exception of the COM (commission) and RUN
10 controls and thereafter functions as a burner control system capable of providing its stored valve setting data in response to a remote load control input.

Following the operation of the RUN control as described above, the system waits for 20 second (24)
15 and then responds to the remote control, checking periodically for a change in demand (25).

Further shown in Fig. 4, the combustion process control system may be reprogrammed by switching it off and on (return to 1), and then operating the COM control
20 on the front panel which returns it to the commissioning cycle via check point (27) and decision (28).

Referring still to Fig. 4, should the flame be extinguished by external influences, the system switches off (29) and will restart when the pilot flame is
25 reestablished (30 to 37).

The programmer/operator is required to set, by means of a presettable control forming part of the apparatus, an "offset" temperature difference to be

used by the apparatus in normal operation. The function of the "offset" temperature difference and the relationship between the START, INTERMEDIATE, and HIGH settings will now be explained with reference to Fig. 5.

5 In Fig. 5, the relationship between the fuel valve setting and the deviation of the actual temperature from the thermostatically set temperature is represented by a graph having two straight portions, one (the first) portion rising at a constant rate to meet the other
10 portion which has zero slope. The first portion of the graph represents an increasing fuel valve setting, that is, the extent of opening of the fuel valve, from the START value to the HIGH value. The increase in the fuel valve setting from the START value to the HIGH value occurs
15 over a change from 0°C to 10°C in the deviation of the actual temperature from the thermostatically set temperature. The fuel valve setting then remains constant at the HIGH value for temperature deviations in excess of 10°C . It will be appreciated that the thermo-
20 statically set temperature $T^{\circ}\text{C}$ is represented by a 0°C temperature deviation and $T - 10^{\circ}\text{C}$ is represented by a 10°C deviation, as shown in the alternative temperature scale of Fig. 5. The "offset" temperature difference referred to above is, in Fig. 5, the 10°C difference at
25 which the change occurs in the slope of the graph. Values of fuel valve setting which lie on the rising part of the graph are the intermediate fuel valve setting values.

The equipment is capable of "constructing" the graph of Fig. 5 by calculation, since it is given the START value, the HIGH value, and the "offset" temperature difference. As stated above the HIGH value represents
 5 the setting for the maximum heat output which may be used with the particular installation, e.g. a boiler, which incorporates the burner control system.

The fuel burner control system, according to the invention, in operation, monitors the actual temperature
 10 of a medium e.g. water in a boiler, which is being heated by the fuel burner and compares the said actual temperature with a thermostatically set temperature for the medium. The fuel burner control system is capable of calculating the deviation of the actual temperature
 15 from the thermostatically set temperature and also of performing the operations necessary to obtain a value for fuel valve setting for any temperature deviation value in accordance with the relationship represented by Fig. 5. Therefore the fuel burner control system selects the
 20 START value of fuel valve setting if the temperature deviation is zero and selects the HIGH value of fuel valve setting if the temperature deviation is 10° C or more. For a temperature deviation between 0° C and 10° C, the fuel burner control system calculates the fuel
 25 valve setting (angular position in degrees) in accordance with the relationship :-

$$\text{Fuel valve position} = \left[\frac{\text{HIGH fuel valve setting} - \text{START fuel valve setting}}{\text{valve setting}} \right] \times \frac{\text{temp. deviation}}{10}$$

Also shown in Fig. 5 are alternative forms of the relationship between fuel valve settings and temperature deviation having break points at X° C (less than 10° C) and Y° C (more than 10° C), respectively. The fuel burner control system shuts off the fuel supply if the temperature deviation becomes negative.

Referring now to Fig. 6, data required by the fuel burner control system in its operation is stored as fuel valve settings in a first addressable data store, represented diagrammatically on the left in Fig. 6, and as air valve settings in a second addressable data store, represented diagrammatically on the right in Fig. 6. Once the fuel burner control system has determined a fuel valve setting, as described above with reference to Fig. 5, it locates the said fuel valve setting, in the fuel valve setting data store (or the fuel valve setting closest to the said valve setting), notes the address at which the relevant fuel valve setting was located, and selects the air valve setting data at a corresponding address in the air valve setting data store. Once the fuel burner control system has acquired both fuel valve and air valve setting data it proceeds to apply the fuel valve setting data to its fuel valve control output port and to apply the air valve setting data to its air valve control output port.

Referring to Fig. 6, the fuel valve setting data available in the first data store includes control

data giving the following positions of the fuel valve :

CLOSED, at which the fuel valve is shut.

OPEN, at which the fuel valve is open fully.

5 HIGH, at which the fuel valve is open to a position which provides the maximum heat output which the installation, e.g. a boiler, can use.

10 INTERMEDIATE 1 to INTERMEDIATE N, a set of positions along the sloping part of Fig. 5 representing progressive opening of the fuel valve for a minimum heat output START position to the maximum heat output HIGH position. There may be 25 such INTERMEDIATE positions chosen along the sloping part of Fig. 5 ($N = 25$).

15 START, at which the fuel valve is slightly open to provide enough heat to compensate for heat losses of the system in order to maintain the medium being heated at the thermostatically set temperature (T in Fig. 1).

20 The data store also includes an indication of the value of N (the number of INTERMEDIATE positions of the fuel valve available in the data store), so that the system can check on whether or not it holds a full set of INTERMEDIATE data.

25 Referring again to Fig. 1, the accuracy of control of the air and fuel valves 2 and 3 is of the order of a quarter degree and the valve positions are read as those of the motors 4 and 5 by the feedback provided by the potentiometers 6 and 7. The positions of the motors

are checked eight times per second.

Referring again to Fig. 3, the front panel displays include "fuel selected" indicators, "commission" and "run" indicators, and a temperature indicator which
5 displays the desired and actual temperatures alternately. The front panel also includes an O₂ display and setting control for establishing an optimum level of oxygen in the exhaust gases during commissioning. The system may be arranged to maintain a boiler to provide the optimum
10 oxygen level in the exhaust gases by fine control of the valves (over and above the fixed control set on commissioning). The O₂ display is arranged to display the actual and desired values alternately.

In the equipment described above the temperature
15 (or more precisely the difference between the actual and desired temperatures) of the boiler water is used as a variable control quantity. It is also possible to use other variables; for example the steam pressure of the boiler, the temperature of the products of combustion
20 of the boiler, the process or output temperature of the boiler, or a variable related to the heat load requirements of, for example, a building heated by the boiler.

Claims:

1. A control system for a fuel burner, the system having a commissioning mode and a run mode and comprising a fuel valve and an air valve, a memory holding values of air valve and fuel valve settings and a processor operable, in 5 the run mode, to provide, from the memory and in response to each of a plurality of input signal values representing values of a first variable, respective values for air valve and fuel valve settings wherein the processor is operable, in the commissioning mode, to effect entry into the memory of the 10 said values of air valve and fuel valve settings and wherein each of those values is derived from an operator selection of the settings of at least one of the valves.
2. A fuel burner control system, including a memory and processor means, operable in a commissioning mode under the 15 control of the processor means, in cooperation with operator controlled means, to effect the generation of output values for setting a fuel valve and an air valve and to effect the entry of values for fuel valve settings and corresponding air valve settings into the memory, and operable in a run mode to provide, 20 in response to each of a plurality of input signal values representative of respective values of a first variable, the appropriate stored values for fuel valve and air valve settings.
3. A control system as claimed in claim 1 or claim 2, wherein the processor is capable of determining a setting value 25 for one valve for each value of the first variable, and is arranged to select increasing setting values for the valve

with increasing values of the first variable over a limited range of values of the first variable, and outside the limited range, to select a fixed setting value for the valve.

4. A control system as claimed in claim 3, wherein the limited range of values of the first variable lies between five and twenty percent of the possible range of the first variable.

5. A control system as claimed in claim 3 or claim 4, wherein the processor includes means for adjusting the limits of the limited range of values of the first variable.

6. A control system as claimed in any one of the preceding claims, wherein the memory is so organised that the address of each fuel valve setting value points to the address of the corresponding air valve setting value, or vice-versa.

7. A control system as claimed in any one of the preceding claims, which includes data as to the number of valve settings the memory is intended to accommodate and is capable of operating in a run mode only when all the air and fuel valve settings are present in the memory.

8. A control system as claimed in any one of the preceding claims, wherein the memory holds data as to the open and shut positions of the valves.

9. A control system as claimed in any one of the preceding claims, wherein the first variable is the difference between second and third variables.

10. A control system as claimed in claim 9, wherein the second and third variables are the actual and desired operating temperatures, respectively, of a medium arranged to be heated by a burner controllable by the control system.

5 11. A control system as claimed in claim 9 or claim 10, including display means and capable of displaying the second and third variables alternately on common display elements.

12. A boiler installation including a control system as claimed in any one of the preceding claims.

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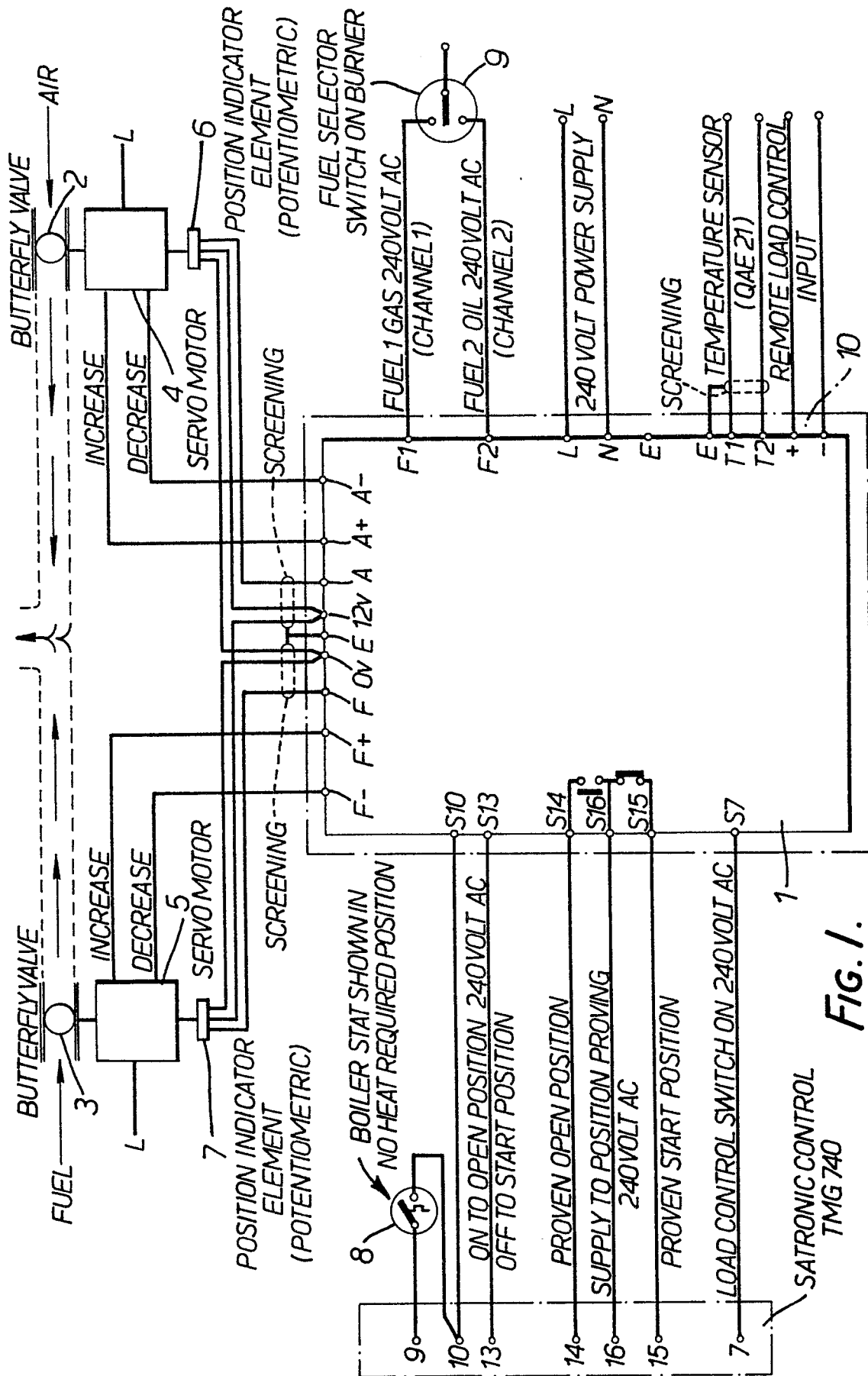


FIG. 1.

SATRONIC CONTROL TMG 740

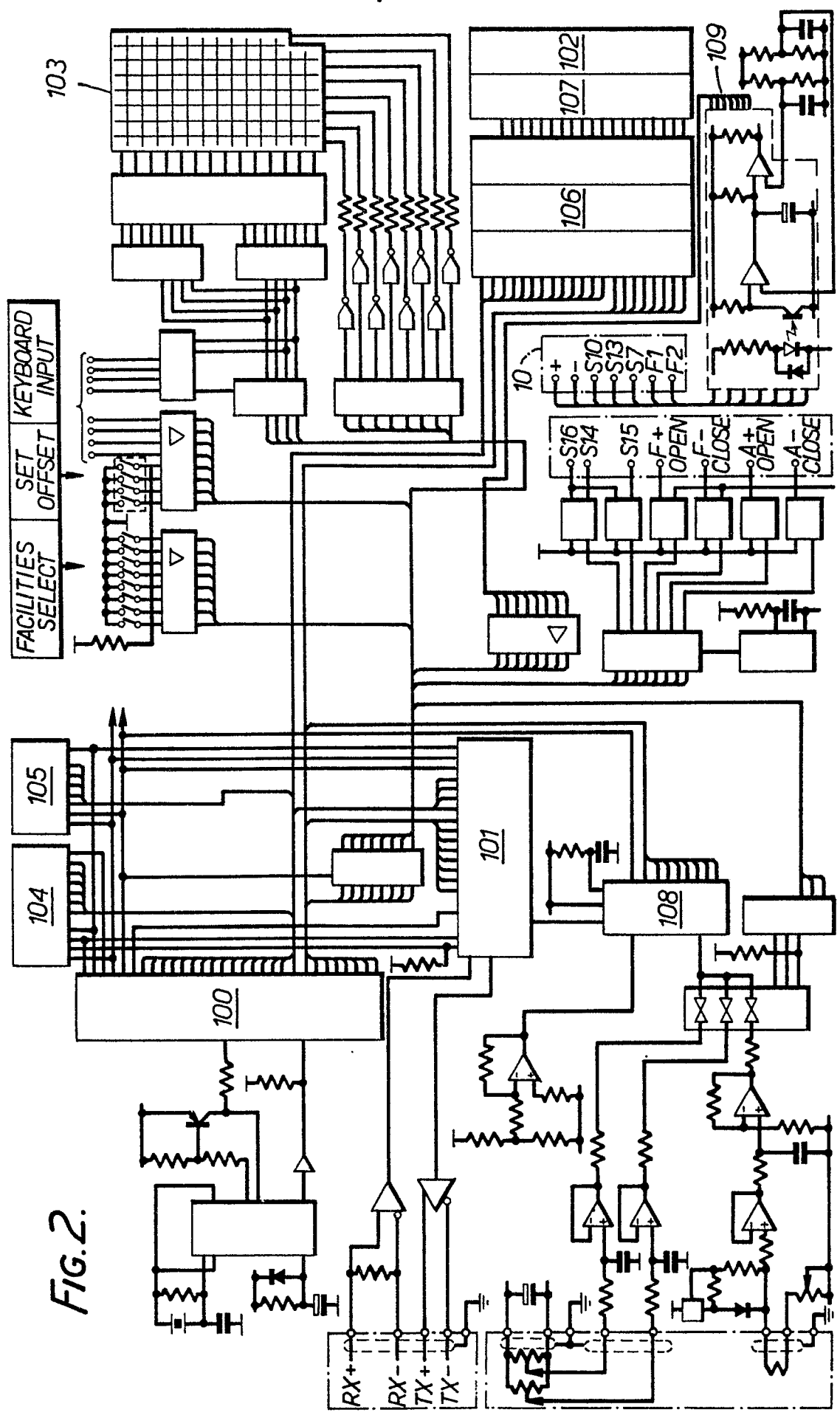


FIG. 2.

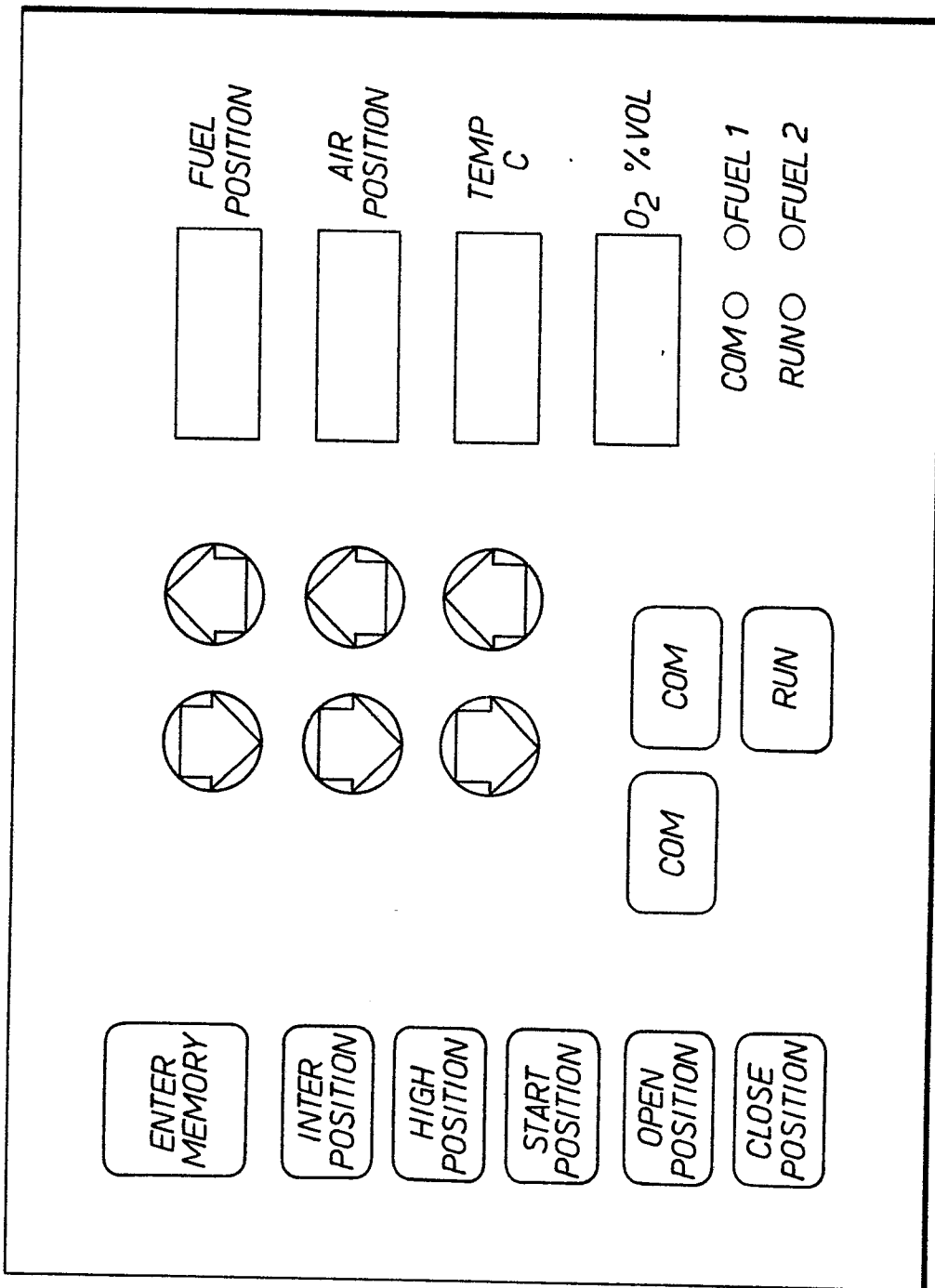


FIG. 3.

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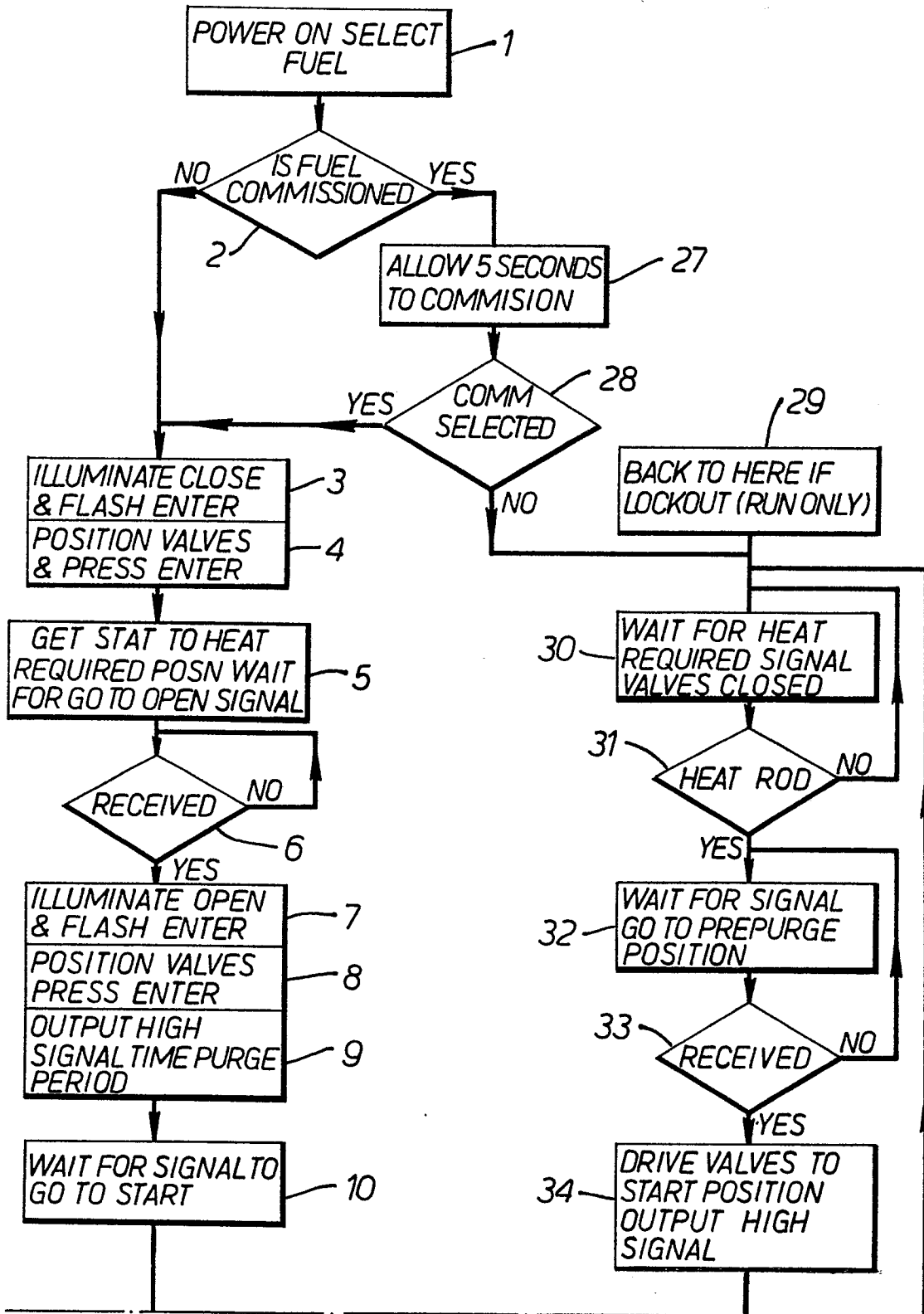


Fig. 4a

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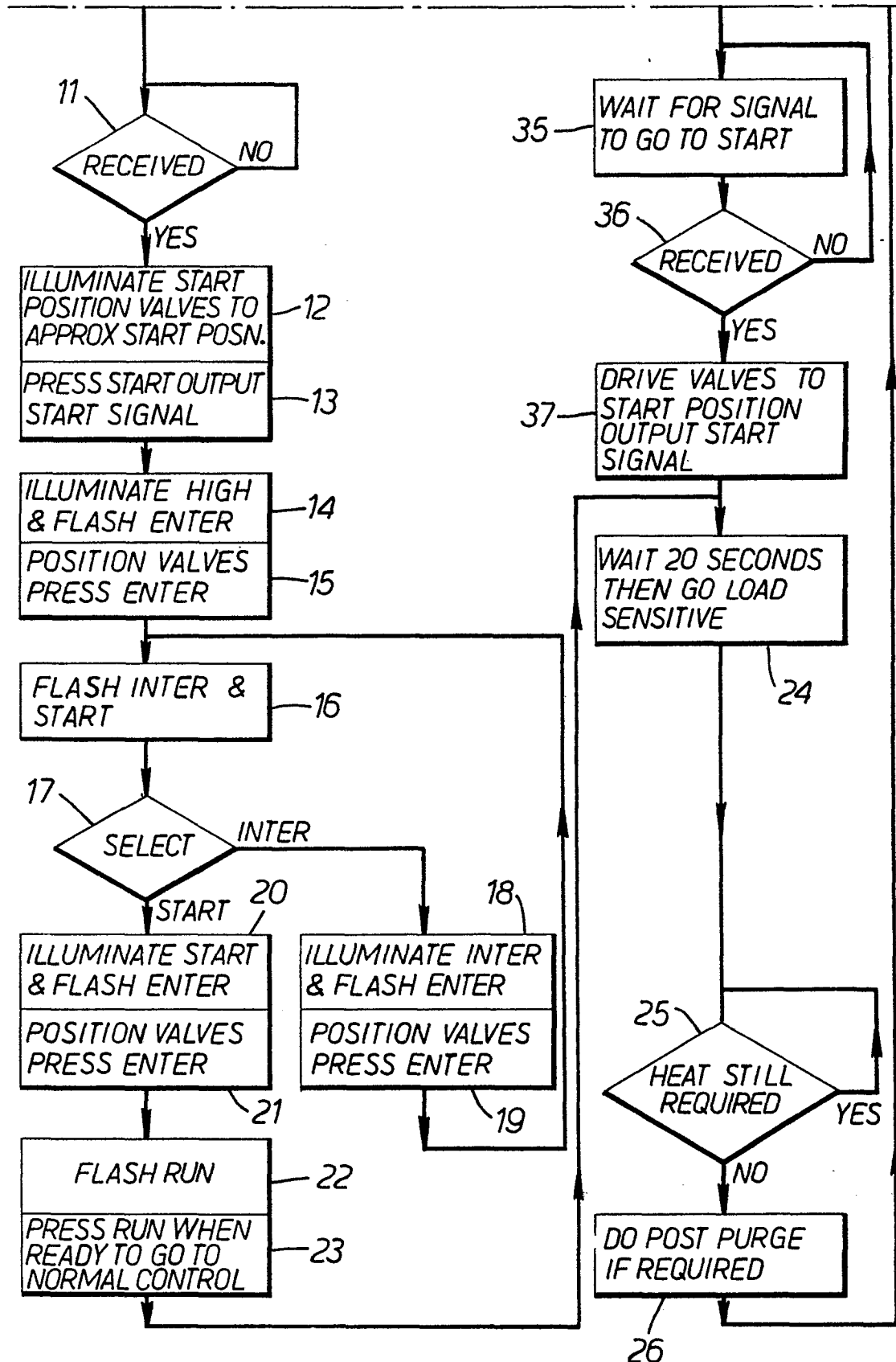


Fig. 4b

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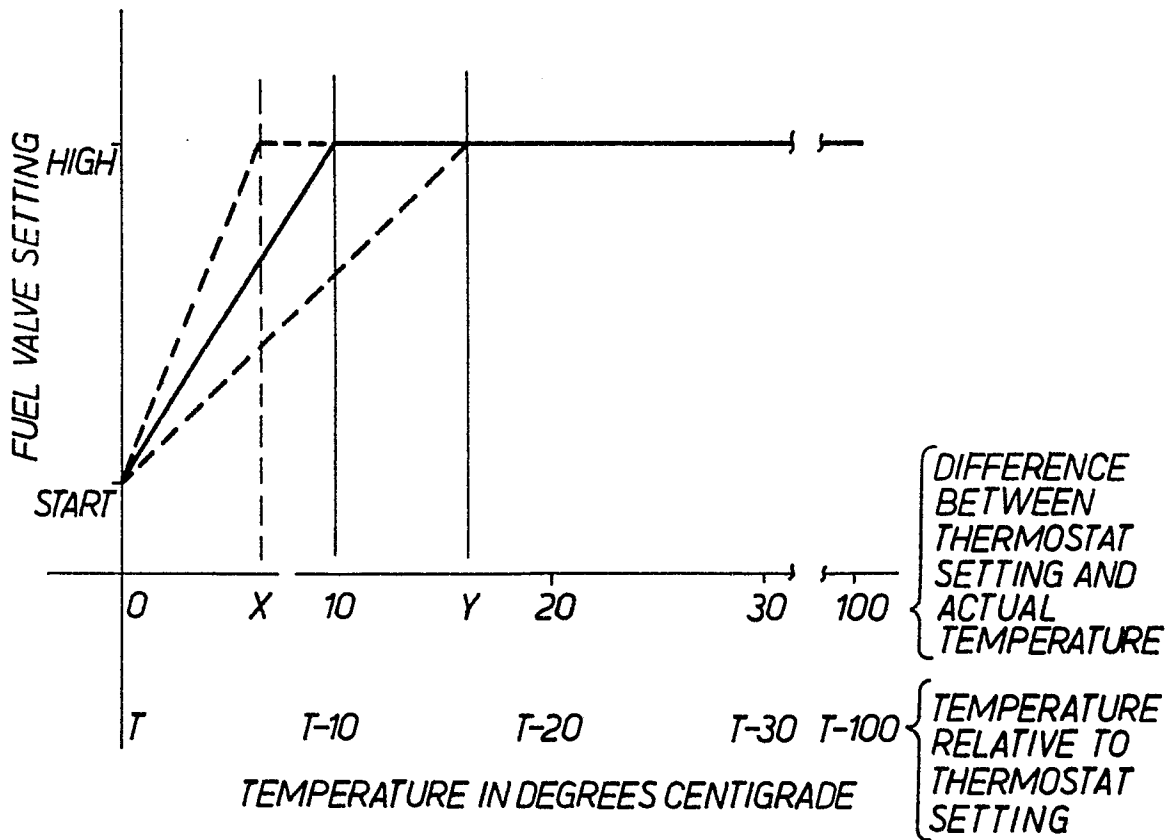


Fig. 5.

T=THERMOSTAT SETTING

FUEL VALVE SETTINGS		AIR VALVE SETTINGS	
ADDRESS		ADDRESS	
1	CLOSED	1	CLOSED
2	OPEN	2	OPEN
3	HIGH	3	HIGH
4	INTER 1	4	INTER 1
5	INTER 2	5	INTER 2
6	INTER 3	6	INTER 3
	⋮		⋮
26	INTER N	26	INTER N
27	START	27	START
30	N	30	N

Fig. 6.



DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
X	DE-A-3 010 147 (LICENTIA PATENTVERWALTUNGS-GmbH) * Figures 1-7; page 7, line 6 - page 8, line 34; page 12, line 11 - page 16, line 19 *	1,2,6	F 23 N 1/02
A	---	3,7,9	
A	US-A-4 296 727 (E.L. BRYAN) * Figures 1-10; abstract; column 4, lines 6-10 *	5,9-11	
A	EP-A-0 050 840 (KARL DUNGS GmbH. & CO.)		
A	PATENTS ABSTRACTS OF JAPAN, vol. 7, no. 50 (M-197)[1195], 26th February 1983; & JP - A - 57 198 920 (KURASHIKI BOUSEKI K.K.) 06-12-1982		
			TECHNICAL FIELDS SEARCHED (Int. Cl. ³)
			F 23 N
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 16-07-1984	Examiner THIBO F.
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		& : member of the same patent family, corresponding document	