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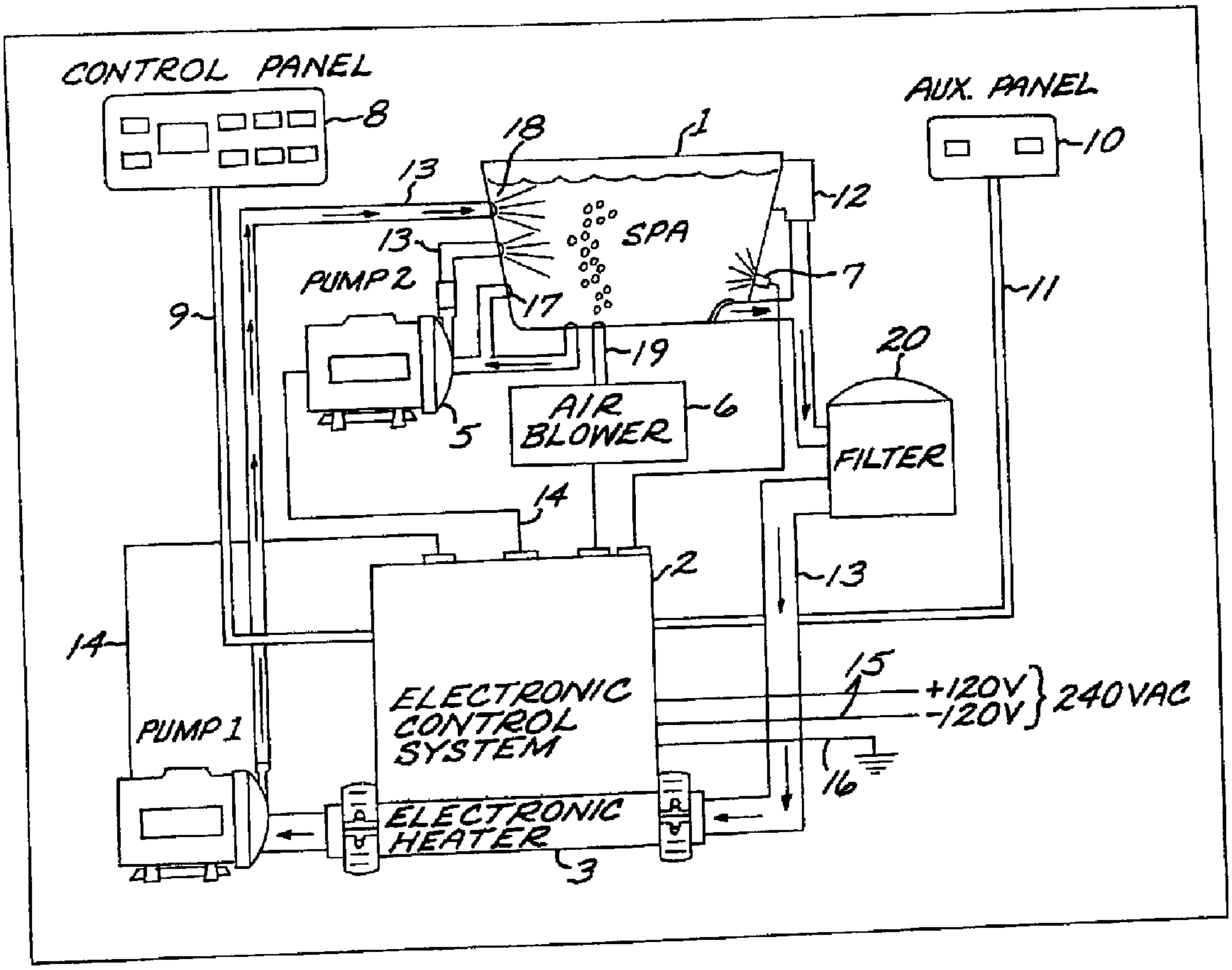


(57) Abrégé/Abstract:
A control system for bathers includes an electronic controller which controls operation of an electric heater assembly connected in a water flow path for heating water. The heater assembly includes a heater housing and electric heater element. A solid state water

(57) Abrégé(suite)/Abstract(continued):

temperature sensor apparatus provides electrical temperature signals to the controller indicative of water temperature at separated first and second locations on or within the heater housing. The presence of water in the heater housing is detected electronically, by turning on the heater, and monitoring the temperature sensors for unusual temperature rises or other faults for a period of time thereafter. A solid state water presence sensor apparatus can also be used to determine the presence of water within the heater housing, providing electrical water presence signals to the controller indicative of the presence or absence of a body of water within the heater housing. An independent circuit apparatus is connected to the water temperature sensor apparatus and to a power relay, automatically causing high voltage power to be disconnected from the heater assembly when the water temperature exceeds a predetermined temperature. The independent circuit apparatus requiring a manual reset once the water temperature has dropped below a predetermined level to allow the high voltage power to be reconnected to the heater assembly. The system includes ground continuity detection, ground current detection and ground fault detection circuits.

ABSTRACT OF THE DISCLOSURE

A control system for bathers includes an electronic controller which controls operation of an electric heater assembly connected in a water flow path for heating water. The heater assembly includes a heater housing and electric heater element. A solid state water temperature sensor apparatus provides electrical temperature signals to the controller indicative of water temperature at separated first and second locations on or within the heater housing. The presence of water in the heater housing is detected electronically, by turning on the heater, and monitoring the temperature sensors for unusual temperature rises or other faults for a period of time thereafter. A solid state water presence sensor apparatus can also be used to determine the presence of water within the heater housing, providing electrical water presence signals to the controller indicative of the presence or absence of a body of water within the heater housing. An independent circuit apparatus is connected to the water temperature sensor apparatus and to a power relay, automatically causing high voltage power to be disconnected from the heater assembly when the water temperature exceeds a predetermined temperature. The independent circuit apparatus requiring a manual reset once the water temperature has dropped below a predetermined level to allow the high voltage power to be reconnected to the heater assembly. The system includes ground continuity detection, ground current detection and ground fault detection circuits.

CONTROL SYSTEM FOR BATHERS

TECHNICAL FIELD OF THE INVENTION

This invention relates to control systems for bathing systems such as portable spas.

BACKGROUND OF THE INVENTION

A bathing system such as a spa typically includes a vessel for holding water, pumps, a blower, a light, a heater and a control for managing these features. The control usually includes a control panel and a series of switches which connect to the various components with electrical wire. Sensors then detect water temperature and water flow parameters, and feed this information into a microprocessor which operates the pumps and heater in accordance with programming. U.S. Patent Nos. 5,361,215, 5,559,720 and 5,550,753 show various methods of implementing a microprocessor based spa control system.

For a properly designed system, the safety of the user and the equipment is important, and is typically concerned with the elimination of shock hazard through effective insulation and isolated circuity, which prevents normal supply voltage from reaching the user. Examples of isolation systems for spa side electronic control panels are described in U.S. Patent Nos. 4,618,797 and 5,332,944.

SUMMARY OF THE INVENTION

Accordingly, in one aspect there is provided a heating and control system for bathers, comprising:

an electronic controller;

an electric heater assembly connected in a water flow path for heating water passing therethrough and comprising a heater housing and an electric heater element, the controller arranged to control the operation of the heater element, the heater assembly including a water conduit having a first port and a second port;

a water temperature sensor apparatus providing electrical temperature signals to the controller indicative of water temperature at separated first and second locations on or within said heater assembly or a combination thereof; and

a solid state water presence sensor apparatus to determine the presence or absence of water within said heater assembly, and to provide electrical water presence signals to the controller indicative of the presence or absence of a body of water within the heater assembly, said water presence sensor free of any moving parts in the flow path;

the controller responsive to signals from the water temperature sensor apparatus and the electrical water presence signals to control the heater assembly, said controller responsive to said electrical water presence signals indicating the absence of a body of water to disable operation of the heater assembly;

wherein the heater assembly may be connected in the water path in a first orientation with the water entering the first port and exiting the second port, or in a second orientation with water entering the second port and exiting the first port, with the water presence sensor operational with the heater assembly in the first orientation and with the heater assembly in the second orientation.

According to another aspect there is provided a spa system for bathers, comprising:

a vessel for holding a body of water;

a water heater assembly having a first input/output port and a second input/output port, the assembly connected in a water recirculation path coupled to the vessel;

a water presence sensor apparatus to determine the presence of water within the heater assembly and provide water presence signals indicative of the presence or absence of a body of water within the heater assembly;

a pump having an inlet port and an outlet port connected in the water recirculation path for recirculating water through said heater assembly and said vessel;

a water temperature sensor apparatus providing electrical temperature signals indicative of water temperature at separated first and second locations on or within said heater assembly, the sensor apparatus free of any moving parts within the water recirculation path;

the water heater assembly configured for connection in the water recirculation path either upstream of the pump inlet port or downstream of the pump outlet port, and with either the first input/output port or the second input/output port connected in the water recirculation path as the water heater inlet; and

an electronic controller for selectively activating and deactivating said pump at selected time intervals, said controller responsive to said temperature signals and said water presence signal to manage water parameters.

According to yet another aspect there is provided a heater assembly for use in a bathing installation, comprising:

a heater housing defining a water conduit having a first port and a second port, wherein the first port and the second port are aligned along a heater axis;

an electrically actuated heater element for heating water passing through the heater housing; and a water temperature sensor apparatus providing electrical temperature signals indicative of water temperature at separated first and second locations on or within said heater assembly or a combination thereof, said water temperature sensor apparatus comprising a first temperature sensor mounted to said housing near said first port and a second temperature sensor mounted to said housing near said second port.

According to still yet another aspect there is provided a heater assembly for use in a bathing installation, comprising:

a heater housing defining a water conduit having a first water port and a second water port, the first water port and the second water port arranged for connection in a water flow path of the bathing installation; and

an electrically actuated heater element for heating water passing through the heater housing, the heater housing having first and second sensor port openings formed therein to receive respective first and second temperature sensors providing electrical temperature signals indicative of temperature at separated first and second locations on or within said heater assembly, said first sensor port opening near said first port and said second sensor port opening near said second port;

wherein the heater assembly is further configured to be connected in the water flow path in a first orientation with the water entering the first port and exiting the second port, or in a second orientation with water entering the second port and exiting the first port.

BRIEF DESCRIPTION OF THE DRAWING

These and other features and advantages of the present invention will become more apparent from the following detailed description of an exemplary embodiment thereof, as illustrated in the accompanying drawings, in which:

FIG. 1 is a schematic diagram of a system for bathers including a vessel for holding bathing water, a control system, and associated water management equipment.

FIG. 2A is a schematic block diagram of an embodiment of a control for a bathing system with various safety and water management features.

FIG. 2B is an isometric view of an exemplary embodiment of the control circuit board assembly enclosure and attached heater assembly.

FIG. 3 is an electrical schematic diagram showing one embodiment of a water detection safety and water management electrical circuits associated with a system for bathers.

FIG. 4 is an electrical schematic diagram of one embodiment of a ground fault circuit interrupter circuit integrated into a system for bathers.

FIG. 5 shows a Ground Integrity Detector circuit to detect and identify a disconnected ground.

FIG. 6 is a schematic diagram of a Ground Current Detector circuit to identify and detect when current is flowing through the earth grounding circuit of the spa wiring.

FIG. 7A is a cross-sectional diagram of a temperature sensor assembly showing the conductive casing and the components therein.

FIG. 7B is a simplified flow diagram illustrating a technique for detecting the presence of water in the heater housing.

FIG. 8 illustrates a partial program structure showing relevant relationship of a main program block.

FIG. 9 is a flow diagram illustrative of a panel service program which responds to button activation to change operational modes of the spa.

FIGS. 10A-10B represent a flow diagram illustrating the operation of a safety circuit, temperature measurement and water detection method.

FIG. 11 is a flow diagram illustrating a technique for self calibration of temperature sensors and display of error message.

FIGS. 12A-12B represent a flow diagram illustrative of a program to monitor a safety circuit, temperature rate of rise, GFCI and temperature sensor short/open detection.

FIGS. 13A-13B represent a flow diagram of a standard mode of operation of a program for intelligent, temperature maintenance using rate of heat loss to drive sampling frequency schedule.

FIG. 14 is a flow diagram of an economy mode of operation of a program for temperature management.

FIG. 15 is a flow diagram of a standby mode of operation of a program for temperature management.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 illustrates an overall block diagram of a spa system with typical equipment and plumbing installed. The system includes a spa 1 for bathers with water, and a control system 2 to activate and manage the various parameters of the spa. Connected to the spa 1 through a series of plumbing lines 13 are pumps 4 and 5 for pumping water, a skimmer 12 for cleaning the surface of the spa, a filter 20 for removing particulate impurities in the water, an air blower 6 for delivering therapy bubbles to the spa through air pipe 19, and an electric heater 3 for maintaining the temperature of the spa at a temperature set by the user. The heater 3 in this embodiment is an electric heater, but a gas heater can be used for this purpose also. Generally, a light 7 is provided for internal illumination of the water.

Service voltage power is supplied to the spa control system at electrical service wiring 15, which can be 120V or 240V single phase 60 cycle, 220V single phase 50 cycle, or any other generally accepted power service suitable for commercial or residential service. An earth ground 16 is connected to the control system and there through to all electrical components which carry service voltage power and all metal parts. Electrically connected to the control system through respective cables 9 and 11 are the control panels 8 and 10. All components powered by the control system are connected by cables 14 suitable for carrying appropriate levels of voltage and current to properly operate the spa.

Water is drawn to the plumbing system generally through the skimmer 12 or suction fittings 17, and discharged back into the spa through therapy jets 18.

An exemplary embodiment of the electronic control system is illustrated in schematic form in FIG. 2A. The control system circuit assembly board is housed in a protective metallic enclosure 200, as illustrated in FIG.

2B. The heater assembly 3 is attached to the enclosure 200, and includes inlet/outlet ports 3A, 3B with couplings for connection to the spa water pipe system.

As shown in FIG. 2A, the electronic control system 2 includes a variety of electrical components generally disposed on a circuit board 23 and connected to the service voltage power connection 15. Earth ground 16 is brought within the enclosure 200 of the electronic control system and is attached to a common collection point.

Adjacent to the circuit board 23 and connected via an electrical plug, a power and isolation transformer 24 is provided. This transformer converts the service line power from high voltage with respect to earth ground to low voltage, fully isolated from the service line power by a variety of methods well known in the art.

Also provided on the circuit board 23, in this exemplary embodiment, is a control system computer 35, e.g. a microcomputer such as a Pic 16C65A CMOS microcomputer marketed by Microchip, which accepts information from a variety of sensors and acts on the information, thereby operating according to instructions described more fully in FIG. 14. The invention is not limited to the use of a controller including a microcomputer or microprocessor, whose functions can instead be performed by other circuitry, including, by way of example only, an ASIC, or by discrete logic circuitry.

One output of the computer 35 is displayed on the control panel 8 through a character display system rendered optically visible by technology generally known in the art. Tactile sensors 22 are provided to convert user instructions to computer readable format which is returned to the control system computer 35 via cable 9.

The equipment necessary to heat and manage the water quality, i.e. the heater system 3, pumps 5 and 6, blower 4 and light 7, are connected via electrical cables 14 to relays 36, 126, 129 and 130 on the circuit board 23, which function under the control of relay drivers 34, selectively driven by the microcomputer 35. These relays and relay drivers function as electrically controlled switches to operate the powered devices, and are accomplished by methods well known in the art and provide electrical isolation from the service voltage power for the low voltage control circuitry. Of course, other types of switching devices can alternatively be employed, such as SCRs and triacs.

Referring now to FIG. 3, also arrayed upon the circuit board and integral thereto in this exemplary embodiment are several safety circuits, which protect the system in case of error or failure of the components. Shown in the functional schematic diagram of FIG. 3 is the heater system 3, which includes a generally tubular metal housing 3A constructed of a corrosion resistant material such as 316 stainless steel, a heater element 42 for heating the water, a heater power connection 37 from heater relays to the terminal of the heater element, and sensors 31 and 32 connected through lines 40 to appropriate circuity on the circuit board. These sensors are connected on the circuit board to both a hardware high limit circuit 33 (FIG. 2A) and to the computer control circuit 35.

A torroid 30, constructed in accordance with techniques well known in the art, is provided through which the earth ground connection 16 from the heater housing and any other ground connection in the system passes. This torroid is electrically connected by cable 41 to the ground current detector circuitry 29 which is more fully described in FIG. 6. The output of the ground current detector (GCD) is provided to the computer system 35 via an electrical connection through the signal conditioning circuitry.

The service voltage power is provided to the system through the center of a pair of conventional torroids 25 and 26. The electrical outputs of these torroids are connected to a ground fault circuit interrupter circuit 27 by electrical connections shown as 38 and 39. The ground fault circuit interrupter is described more fully in

FIG. 4. The ground fault circuit interrupter feeds a signal to the computer 35, which tells the computer of a ground fault existence. Testing of the ground fault circuit interrupter is managed by the computer on a regular basis, and an exemplary program algorithm of this activity is illustrated in FIG. 11.

A ground integrity detector 28 is provided which is more fully described in FIG. 5. The ground integrity detector is attached to the earth ground 16 and provides a signal to the computer control 35. If more than one earth ground is used in a particular application, another ground integrity detector could be used in accordance with the invention to verify the ground continuity.

FIG. 3 is a schematic diagram of a temperature sensing system for a spa, and comprises the control system. Heater assembly 3 has a heater shell 3A, most usually made of metal, but can also be constructed of conductive plastic or of plastic with an internal metallic ground plate. Confined within the heater shell is a heater element 43, constructed to provide insulation from the water as generally known in the art. Power is provided to the heater element from connection points 124 and 127. This power is provided responsively to the programmed temperature provided to the microcomputer 35 through control panel 22 as is generally known from the prior art.

In this exemplary embodiment, the heater housing 50 is tubular in shape. However, other shapes come within the scope of this invention provided they have an inlet and an outlet. Located close to each end of the heater element are temperature sensor assemblies. These assemblies include thermistors 133 and 134, which are usually of a negative temperature coefficient (d). However, they can be positive temperature coefficient thermistors, thermocouples or any other temperature sensitive means. The temperature sensor is generally potted in epoxy or the like, in stainless steel housings 31 and 32. The stainless steel housings are mounted into the side of the heater assembly with insulating collars, which provides a water pressure seal and an insulative barrier from the heater housing. However, when water is present, there is a conductive path which can be detected by the associated circuitry. This conductive path extends from sensor housing 32 to sensor housing 31 through the water in the housing. When microcomputer 35 sets the output high through resistor pair 78, 79, current travels through connecting wires 141, 143 and the sensor housings 31A, 32A, water between the sensor housings, and voltage divider network created by resistor pair 80, 81, resistor 84, resistor pair 82, 83 and resistor 91. The resulting voltage is buffered to the microcomputer by op amp 90, which is powered and installed according to known techniques.

FIG. 7A illustrates in cross-section an exemplary one of the temperature sensor assemblies 31, 33. The assembly 31 includes a stainless steel or other corrosion-resistant housing 31A, which is mounted into the heater housing using an insulative bushing 31B. The bushing is fabricated of a dielectric material, for example, KYNAR (TM) or polyprophylene, thus electrically insulating the housing 31A from the heater housing. The bushing 31B can have a threaded peripheral surface (as shown) which is threaded into a correspondingly threaded opening in the heater housing. Alternatively or in addition, the bushing can be sealed into the opening with a non-conductive adhesive. The thermistor 133 is mounted at a distal end of the housing 31A, to be positioned within the heater housing in close proximity to the water flow through the heater housing. Wires 144 provide an electrical connection to the thermistor from the circuit 2. A third wire 143 is passed into the housing 31A from circuit 2, and is electrically connected to the housing 31A, e.g. by a solder connection. This connection (wire 143) is used in the water presence detection process. The elements 133 and 143-144 are potted with a potting compound such as epoxy.

In operation previously described, the water detection system is normally held in a low state by the microcomputer output, which is turned off. When the microcomputer program turns the output on, or switches to a high state, if no water is present to form a conductive path, no change is detected at the output of op amp 90. However, if water is present, then the output of 90 changes state in response to state change of the output because of the conductive characteristic of water under electrical current. This circuit is activated for very short periods of time and then returned to an inactive or grounded state. An exemplary effective cycle could be for 5 milliseconds every 100 milliseconds. In addition, it may be advisable to change polarity on each sensor to prevent corrosion damaging one sensor to the point of destruction.

FIGS. 3 and 7A thus illustrate a combination sensor which uses the housing of the temperature sensor for the water presence detector. A separate pair of electrodes distinct from the temperature sensor is also within the scope of this invention, as is the concept of using the shell of the heater housing for one electrode, and an insulated, conductive probe, both hooked to a resistor divider network, as previously described.

Since the water presence detector has no moving parts, water may enter the heater housing from either end and flow out the other end. Generally, a pump has an inlet, or suction side, and an outlet, or pressure side. The heater assembly fitted with the water presence detector may therefore be fitted to either the suction or outlet side of the pump with equally satisfactory results. This flexibility is extremely valuable, as it allows exceptional latitude in the principal layout configuration of the pump and heater components for assembly into the spa.

Temperature information regarding the heater is gained through sensor thermistors 134 and 133, formed and placed generally adjacent to the heater element, and on either end of the heater element. As the thermistors change resistance in response to the immediate temperature surrounding, an electrical signal is generated at the output of op amps 97 and 89, through associated electrical circuitry. Resistors 88, 85 and capacitors 87 and 86 are configured to provide the current form of electrical input to provide a sensible voltage through the op amp. Each temperature sensor is configured in like manner. When water is flowing in the heater assembly, both temperature sensors will reach equilibrium and provide a proportionally equal voltage if the heater element 42 is not activated.

Under control of the microcomputer, if the heater element is energized, the physical location of the temperature sensors may then detect a different temperature of water between the inlet and the outlet of the heater housing. Depending on the actual set temperature of the controller, the microcomputer will elect to use the temperature of the lower, or inlet side sensor, as the actual temperature of the spa, and turn off the heater when the temperature of the spa is equal to the desired temperature of the spa.

If the water flow slows down to a point where there is a substantial difference between the inlet and outlet temperature, then the microcomputer can interpret this as a trouble signal and deactivate the heater. Further, if there is a blockage in the plumbing, or the pump fails to circulate water, the temperature in the heater housing may rise to unacceptable limits. Accordingly, op amps 105 and 104, not feeding into the microcomputer, but entirely independent circuit have a reference network of resistors which provides a precision reference voltage. When the input to either of the op amps 104, 105 exceeds the precision reference voltage, the output of the op amp swings appropriately to deactivate transistor 133 thereby causing gate 118 to change state, and causing relay driver 131 to turn off heater relays 130 and 129. The heater is therefore shut off and can only be reactivated by a manual reset signal from control panel 22, through the microcomputer, which changes state of gate 118. However, as long as either temperature sensor remains above a temperature set by the reference voltage networks, the manual reset signal cannot work. An exemplary appropriate temperature for the high limit circuit deactivation is between 118°F and 122°F to protect from injury. As long as a manual reset signal is not given, the circuit will remain in an off state.

Each described circuit is sensibly connected to the microcomputer 35, which has electrical inputs responsive to changes in voltage level from a logic high to a logic low. An exemplary embodiment employs a relatively sophisticated microcomputer, and 8 bit microcomputers and more powerful microcomputers can be employed. Typically an embodiment of this invention would employ a CMOS or complimentary metal oxide version of a microcomputer.

Because the temperature sensors 31 and 32 generate a voltage proportional to temperature, a device such as an analog to digital converter 99 is used to convert the analog voltage to a readily usable digital value which is provided at the microcomputer via customary means. In a preferred embodiment, the temperature measurement components are thermistors which are matched in their resistance versus temperature values. Typically, accuracies are available of .2°C precision, meaning two thermistors held at a precise resistance value by varying the temperature of each independently will match within .2°C of an equal temperature. By using thermistors of no more than 1°C precision, the system will not require calibration of the hardware interface of the electrical signal of the thermistor temperature output. In addition, if the computer is able to circulate water through the system without activating the heater, the temperature sensors will be in the same temperature environment. Therefore, the computer will able to compare the readings of the sensors to determine if they are within the precision specified above, 1°C, and provide a software calibration for final correction.

An additional or alternative technique for sensing the presence of water in the heater housing is illustrated in the flow diagram of FIG. 7B. This embodiment senses the water flow, which will tend to cool the heater and temperature sensor assemblies. In the absence of water or water flow, with the heater energized, the temperature sensors will detect a significantly increased rate of temperature rise. This can then be used to determine that no water is present or that components have failed (e.g., water pump failure). While the water pump 1 is activated, the microprocessor 35 may activate the heater 3 for a selected period of time, say 4 seconds, deactivate the heater for a selected period of time, say one minute, and compare the temperature readings before the activation began to the readings after the selected off time interval. If the temperature difference exceeds a predetermined amount, say 10 degrees, then the heater can be determined by the microprocessor to have no water present in the housing. This technique is illustrated in FIG. 7B with a an operational subroutine executed by the microprocessor. The water pump is activated during the steps 350-356. At step 350, a first temperature reading at both of the temperature sensors is taken with the heater off. Then, the heater is turned on for a predetermined time interval (step 353) and then turned off. After another time interval has elapsed (step 354), a second temperature reading is taken (step 356). The difference between the two readings for each temperature sensor is then taken, and compared to a threshold (step 358). If the difference for either sensor is greater than this threshold, then the microprocessor declares that no water is present or that there is a component failure (step 360). If the difference is not greater than the threshold, the microprocessor determines (step 362) whether any other faults have been detected, such as too large a differential between the temperature readings taken at the two sensors 31, 33 (described more fully below). If so, the operation branches to step 360. Otherwise, the microprocessor will determine that water is present in the heater housing (step 364).

Shown in FIG. 4 is a Ground Fault Circuit Interrupter (GFCI) circuit. This electrical circuit is configured to be in close relationship with the electrical system which controls the spa equipment. The main power supply which supplies the current to the spa equipment and control is shown at 15, and passes through two torroids, shown at 25 and 26. As long as the net current flowing through the torroids is equal, the torroids see a no magnetic flux. However, if a device, such as a heater element fails, some current escapes through the earth ground, as at 16.

When an imbalance occurs, an electromagnetic coupling occurs which sets up an electrical current in the sense circuit 150 associated with the detection torroids. The circuit 150 outputs a fault or error signal proportional to current flow which is provided to the microcomputer (via analog-to-digital conversion, not shown in FIG. 4). The microcomputer then responds with an error message which is displayed on the control panel 22. In addition, a fault creates a change in state at output connection 116, which connects to 117 on FIG. 3. This connection activates the circuits generally beginning at diode 109. This in turn triggers transistor 133. Gate 118 changes state in response, deactivating relay driver 131 and opening relays 129 and 130d. Microcomputer 35 also opens all other relays, 36, disconnecting any other components, such as pumps, blowers and lights.

Microcomputer 35 can test the functionality of the GFCI circuit by outputting a signal through resistor 56, which activates transistor 54, closing relay 52. Current passes through resistor 23, bypassing torroids 25 and 26, imbalancing the current flowing through the torroids. This causes GFCI circuitry to trigger, providing a signal to microcomputer 35 that the circuit has properly triggered. When the microcomputer senses a trigger signal, it resets test relay 52 by restoring status to resistor 56. Because a GFCI fault triggers the high limit relays 129 and 130, opening them up, the microcomputer also generates a system reset signal on line 198 which re-enables the drivers which activate the relays 129 and 130. This sequence of events is carried on periodically, such as once per day, to verify the functionality of the GFCI circuit. Generally, a real time clock, functioning as a master timekeeper, would provide a reference signal and a programmed interval between tests, such as 24 hours could be set using techniques known by ones skilled in the art of microcomputer programming.

FIG. 5 illustrates a Ground Integrity Detector (GID) device. The Ground Integrity Detector includes a neon bulb 20 connected in series with a limiting resistor 43 from the power service voltage to the system earth ground 16. If the ground is properly connected, current will flow from the supply, through the limiting resistor. The current flow can be limited to less than one milliampere (ma). The light from the neon bulb is contained in a light tight enclosure 28, which also contains an opto-resistive device which falls in resistance in the presence of light. By connecting this opto-resistive device in a resistor divider circuit, shown generally at 46, a signal indicating the presence of light and therefore of a good ground, can be presented to the computer control system. The computer control system then manages this information according to instructions more fully described in FIG. 11.

Shown at FIG. 6 is a Ground Current Detector (GCD). The ground current detector is shown as capable of detecting currents which might flow in a ground attached to a heater current collector or shell 50 which is part of the heater assembly 3, including a heater element 42, and any other device powered or containing line voltage, such as lights, blowers and pumps, and the enclosure itself.

As an example, in normal service, heater elements 42 may fail and rupture due to either mechanical failure, corrosion, or electrical breakdown. The shell of the heater 50 then collects the current and routes it through the ground line, thereby protecting both the occupant of the spa and the equipment. However, if the current is allowed to flow indefinitely, there is a possibility of health hazard or equipment damage occurring. When current flows through the ground line 16, an electromagnetic coupling occurs between the current and the torroid 30 through which it passes. This coupling creates a voltage proportional to the current, and if the current is an AC current, an AC voltage will be induced in the torroid. When this voltage is provided to a full wave rectifier comprising sense circuit 152, a rectified DC signal is created. After conditioning this rectified DC signal with a capacitor 48 and resistor 49, a DC signal is generated proportional to current flow. (Alternatively, circuit 152 with its full wave rectifier can be replaced with a sense circuit similar to circuit 150 (FIG. 4), producing an error signal proportional to current flow.) When no current is flowing, the bleed resistor 50 insulates the circuit from the electrical noise. The computer control 35 consistently monitors the state of the input signal line from the GCD circuit. If a ground current is detected, the computer responds in accordance with instructions more fully explained in FIG. 11 to shut off the relays 36 through relay drivers 34 to reduce hazards to equipment and personnel.

Referring now to computer flow diagrams at FIGS. 8-13, the functional interrelation of the various prior described components is disclosed. These flow diagrams illustrate the action which is directed by the computer 35, as shown on FIG. 2A, responding to signals generated from the control panel 22 through interconnect cable 9.

The microprocessor is programmed to accomplish the functions illustrated therein.

As shown in FIG. 8 in block form, and more fully disclosed in FIGS. 9-14, the spa control system computer is constantly running a safety and error detection program. At any time in this program, a control panel signal can interrupt the program, branching off into the panel service program. When the mode button is pressed, the program branches into the "mode selection" routine, shown in FIGS. 10A-10B. In the mode selection routine, one of three modes is selected, standard, economy or standby. Once a time interval has passed without further button presses, typically 3 seconds, the program reverts back to the safety program, looping through the proper "mode" program also. When the control system is first energized, it is default programmed to start in the economy (econ) mode.

To more fully describe the process diagrammed, the steps are described below.

FIGS. 10A-10B

Step 225. Starting point of the program for flow chart purposes. Program normally initializes by known means to clear and reset all registers upon power up.

Step 226. Check for presence of water in heater. If none, branch to 227, otherwise branch to 228.

Step 227. Disable heater and loop back to 226.

Step 228. Check for software set high limit of 118°F. If temperature at either temperature sensor exceeds this value, the heater is turned off. If less than 118°F, program loops to 232.

Step 229. Turn heater off.

Step 230. Display error message on control panel 8 of OH2 to signify overheat - at least 118°F.

Step 231. Remeasure temperature sensor. If temperature exceeds 116°F, program loops back to Step 229. If less than 116°F, program loops to Step 228.

Step 232. Check for hardware high limit, if tripped branch to 233, otherwise 237.

Step 233. Shut down system.

Step 234. Display error condition "OH3" for overheat hardware high limit.

Step 235. Measure water temperature. If less than 116°F, then branch to 236, otherwise branch to 233.

Step 236. Check for control panel input. If any button is pressed, system will reset.

Step 237. If water temperature is over 112°F, branch to 238, otherwise go to 241.

Step 238. Turn off everything - branch to 239.

Step 239. Display system error message "OH1" for overheat of at least 112°F.

Step 240. Remeasure water temperature, if less than 110°F, branch to 240, otherwise branch to 241.

Step 241. Check for balance between water temperature sensors. If a difference of greater than 5°F exists, branch to 242, otherwise branch to 244.

Step 242. Turn heater off. Branch to 243.

Step 243. Display error message HFL, meaning the water flow in the heater is too low. Branch to 241.

Step 244. Proceed to 273.

FIG. 11

Step 273. If the heater is on, proceed to 274. If not, proceed to 340.

Step 340. Measure output of temperature sensor 1.

Step 341. Measure output of temperature sensor 2.

Step 342. Subtract lowest value from highest value.

Step 343. If the result is less than or equal to 1°F, then proceed to 345, otherwise proceed to 344.

Step 344. Send error message "CAL" to display on control panel. Proceed to 274.

Step 345. Store result in lowest sensor value register.

Step 346. Add contents of calibration register to all temperature measurement operations. Proceed to 274.

FIGS. 12A-12B

Step 250. Has either sensor changed temperature more than 2°F/second? If so, proceed to 251, otherwise proceed to 253.

Step 251. Turn off heater, proceed to 252.

Step 252. Display "HTH1" error message for heater imbalance. Proceed to 250.

Step 253. Check proper input for ground integrity, that is, is the ground properly connected. If not, proceed to 254, otherwise branch to 256.

Step 254. Turn off system, proceed to 255.

Step 255. Display error message GR for ground disconnected or not properly hooked up. Proceed to 253.

Step 256. Check for ground leakage current. If none, proceed to 245. If yes, branch to 257.

Step 245. Is GFCI tripped? No, branch to 259. If yes, branch to 246.

Step 246. Shut down system and open all relays. Proceed to 247.

Step 247. Display GFCI error message indicating there is a ground circuit fault. Proceed to 248.

Step 248. Has system reset been pressed from control panel? If yes, loop to 245, otherwise loop to 247.

Step 257. Turn everything off. Proceed to 258.

Step 258. Display GRL error message to indicate ground leakage detected, proceed to 256.

Step 259. Check real time clock. If time is equal to 2:00 am, branch to 260, otherwise proceed to 266.

Step 260. Test ground fault interrupter circuit by closing relay to imbalance current in power supply.

Step 261. Check for GFCI system trip. If yes, proceed to 263, if no branch to 262.

Step 262. Turn off system, proceed to 265.

Step 265. Display error message GFCF for ground fault interrupter circuit failure, proceed to 261.

Step 263. Reset GFCI circuit via microprocessor reset, proceed to 264.

Step 264. Reset hi-limit circuit via microprocessor output. Branch to 266.

Step 266. Is either temperature sensor disconnected? If yes, 267. If no, 269.

Step 267. Turn everything off, proceed to 268.

Step 268. Display SND, loop to 266.

Step 269. Is either temperature sensor shorted? If yes, proceed to 270. If no, 275.

Step 270. Turn off system, proceed to 271.

Step 271. Display error message SNS. Loop to 269.

Step 275. Proceed to mode as selected by panel service program.

FIGS. 13A-13B

Step 276. Program checks for function of pump 1 which circulates water through heater. If pump is already on, program proceeds to 282, otherwise program proceeds to 277.

Step 277. Check for 30 minute elapsed time. If pump has been off for less than 30 minutes, branch back to main safety program at 225. If pump has been off for 30 minutes, proceed to 227.

Step 278. If water temperature has dropped more than 1°F below set temperature in the last hour, proceed to 281, if not, proceed to 279.

Step 279. Reset iteration counter to zero and proceed to 280.

Step 280. Reset 30 minute pump off timer and proceed to 225 main safety program.

Step 281. Turn pump on, proceed to 282.

Step 282. Allow pump to run for 30 seconds. If not, look back to main safety program 225. If so, proceed to 283.

Step 283. Read water temperature, proceed to 284.

Step 284. Check to see if 5 seconds has passed from beginning of water temperature read. If so, proceed to 285, otherwise loop back to 283.

Step 285. Compare water temperature to set temperature. If water temperature higher than set temperature, proceed to 286. If not, proceed to 287.

Step 286. Increment iteration counter, proceed to 290.

Step 287. If water temperature is more than 1°F below set temperature, proceed to 288, otherwise proceed to 286.

Step 288. Reset iteration counters. Proceed to 289.

Step 289. Turn on heater, proceed to 225.

Step 290. Turn off heater, Proceed to 290.

Step 291. Turn off pump. Proceed to 294.

Step 294. Display last valid temperature. Proceed to 280.

Step 280. Reset 30 minute pump off timer. Proceed to 292.

Step 292. Has a button on control panel been pressed in the last 24 hours? If yes, branch to 225. If not, branch to 293.

Step 293. Shift to economy mode. Proceed to 225.

Step 225. Proceed to Safety Circuit Chart A.

FIG. 14

Step 275. Once selected by "mode" selection, main safety program branches into economy mode and proceeds to 300.

Step 300. Program checks for filter cycle. If filter pump is on, program branches to 301, otherwise to 225.

Step 301. Read temperature 1 and store.

Step 302. Read temperature 2 and store.

Step 303. Select lowest of the two temperature readings.

Step 304. If spa water temperature is equal or greater than set temperature, branch to 305; otherwise branch to 306.

Step 305. Turn heater off, proceed to 310.

Step 310. Display last valid temperature. Proceed to 308.

Step 306. Is spa more than .1 degree below set temperature? If yes, branch to 307, otherwise branch to 310.

Step 307. Turn heater on. Proceed to 310.

Step 308. Has a control panel button been pressed in the last 24 hours? If yes, branch to 225. If not, branch to 309.

Step 309. Shift to standby mode and proceed to 225.

FIG. 15

Step 275. Once selected by "mode" selection, main safety program branches into standby mode and proceeds to 325.

Step 325. Program checks for filter cycle. If filter pump is on, program branches to 326, otherwise to 225.

Step 326. Read water temperature 1 and proceed to 327.

Step 327. Need water temperature 2 and proceed to 328.

Step 329. Compare spa water temperature to 15 degrees below set temperature. If spa temperature is less than 15 degrees below set temperature, proceed to 328, otherwise 329.

Step 332. Turn on heater and proceed to 225.

Step 328. Select lowest of the two temperature readings and proceed to 329.

As can be seen from the foregoing specification and drawings, a spa control system is disclosed which is self contained with a plurality of sensors located adjacent the heater element for both temperature regulation and limiting. In the preferred embodiment, the heater and control system are attached together in adjacent proximity, as illustrated in FIG. 1 and FIG. 2B. This provides the greatest protection from mechanical hazards and facilitates the sensing of critical parameters, such as water temperature and water presence. In this preferred embodiment also, a microcomputer is the central processing unit, which receives data from a plurality of sensors in and adjacent to the heater, which provides data for the intelligent management of the user's desires. These user's desires are provided to the control microcomputer via control panels which provide a plurality of easy access for activating functions and features of the spa.

Additionally, integrated as a part of the system interconnect board in the control system, are not only the microcomputer, but also the safety circuity which detects and monitors the integrity of the system ground. In addition, as shown in FIG. 2A, there is a ground fault circuit interrupter circuit which shuts down the system when an insulation failure occurs and there is a short to the bather's water of voltage. All of these functions are self-contained within the control system circuitry and heater, and require no other connection than pumping from or to a pump, power hookup with a ground, and a control panel connection.

In the installation of such a preferred embodiment at the factory, ease of assembly into the spa is facilitated by eliminating external temperature sensors employed in previously known systems, since the sensors are contained within the system enclosure and heater assembly (FIG. 2B). Also eliminated are any calibration requirements for mechanical switches and sensors which might need adjustments. Pumps, blowers and lights are plugably connected to the control system. The user is protected from connection to the supply voltage by the containment of all electrical components within the heater housing and enclosure structure, which is hooked to earth ground.

When the control system is initially energized, the microprocessor checks for presence of water, and if present, starts the pump. As described above, the presence of water can be detected in accordance with aspects of the invention by either the use of water as a conductor, and detecting the flow of electrical current through the water, and/or by use of the technique described with respect to FIG. 7B. (Of course, other water detection techniques could also be employed in the system of FIG. 1, including the conventional mechanical, optical or ultrasonic flow sensors.) If the routine of FIG. 7B is repeated at a slow enough cycle rate, the system will not overheat. If repeated loops through this software routine are executed at frequent intervals, and no water is present, the temperature of one of the temperature sensors will eventually exceed 118 °F, and the hardware high limit circuit will shut down certain aspects of the controller, including the heater as at step 228. As an alternative to waiting for the hardware high limit circuit to shut down powered elements, the first detection of a temperature difference exceeding a predetermined amount, or the occurrence of other faults, can be treated by the controller 35 as a serious fault condition, with the controller causing shutdown of all output relays (e.g. step 362 of FIG 7B). The system may be configured to require a manual restart to be returned to normal operation.

After the water presence test has determined that water is present in the heater housing, the microprocessor reads the temperature sensors, calibrates them, and upon determination that all sub-systems of the control system are within tolerance, starts up the heater, if necessary. When the spa water reaches the set temperature, the heater is turned off, and once the heater element has cooled down, the pump is turned off. Every selected time period, the pump is started up, drawing water through the heater and temperature sensor array. If heat is needed to hold the spa water at the desired temperature, the heater is turned on. If not, then the pump is shut down for a time interval. This time interval is adjusted based on the rate of heat loss from the spa. If the rate of loss is low, the time interval can be extended to reduce wear on the pump.

The spa is generally started in the standard mode, where the set temperature is maintained by the controller as described. When the pump is not running, the temperatures the sensors read do not necessarily reflect the actual spa temperature, due to changes in temperature in the spa equipment environment. Therefore, the last known valid temperature is displayed on the control panel, and it does not change until the pump starts up and runs again on its time interval circulation to check spa temperature.

If the user of the spa has not activated a feature of the spa for a period of time, via the control panel, say 12 hours, the spa can automatically shift into a lower energy consumption state, shown as "economy," where the set temperature is only reached when the spa is filtering. Again, if no activity is experienced at the control panel, the spa can automatically shift into an even lower energy consumption state, the "standby" mode. In the "economy" mode, the last known valid temperature is displayed while the filter pump is not running, and actual temperature is displayed when the pump is running. To warn the user of the mode selection, the display of temperature is alternated with the message "econ".

When in the standby mode, no temperature is displayed, just the message "stby", and the spa pump is filtered on user set or default cycles. The heater is activated only to maintain the spa water at 15 to 20° F below the set temperature to reduce energy consumption and the need for sanitation chemicals.

At any time, if the proper ground is damaged or removed from the spa, the microprocessor disconnects the peripheral equipment, including the heater, and provides an error message to the control panel to warn the users, and provide a diagnostic message to assist in curing the problem. This is accomplished by the GID, FIG. 5. If there is an actual short to ground through the ground wire, the system can be shut down by either a ground current detector as in FIG. 6, or a ground fault circuit interrupter, as in FIG. 4.

If there is an over heat condition, the various software detection methods shut off the heater, but if there is a high limit value of over 118-122° F, the system trips the electronic hookup high limit associated with each temperature sensor. This opens a different set of relays from the temperature regulation relays, shutting down the heater until the temperature falls below a safe temperature, and the system is re-set from the control panel.

A detailed reference summary for exemplary elements shown in the figures for the exemplary embodiment follows:

FIG. 1

Reference	Description
1	Spa with water
2	Electronic control system
3	Heater assembly
4	Pump 1
5	Pump 2
6	Air blower
7	Light
8	Control panel
9	Control panel connecting cable
10	Auxiliary control panel
11	Auxiliary control panel cable
12	Spa skimmer
13	Spa water pumping
14	Electrical cable interconnect
15	Electrical service supple cable
16	Earth ground
17	Suction fitting
18	Jet therapy fitting
19	Air blower supply pipe

FIG. 2A

Reference	Description
21	Display of information
22	Panel touch pads
23	Main circuit board
24	Isolation transformer
25	GFCI Torroid 1
26	GFCI Torroid 2
27	GFCI circuitry
28	Ground Integrity

29	Ground Current Detector
30	GCD Torroid
31	Sensory Assembly 1, temp & H_20 detect
32	Sensory Assembly 2, temp & H_20 detect
33	High limit circuit
34	Relay drivers
35	Microcomputer
36	Relays
37	Heater power interconnect
38	GFCI Torroid 1 interconnect
39	GFCI Torroid 2 interconnect
40	Temp sensor interconnect
41	GCD Torroid interconnect
42	Heater element

FIG. 3

Reference	Description
22	Control panel
3	Heater assembly
16	Earth ground
31, 32	Temperature sensor assembly
44, 77	Electrical connection leads
78, 79, 82, 83	Resistor 430 kohm
80, 81	Resistor 820 kohm
84, 115	Resistor 10 kohm
113,112,85,94,98,107	Resistor 20 kohm
86, 92	Capacitor 0.1 microfarad
87, 93	Capacitor 22 microfarad
88, 95	Resistor 2 kohm
122,89,97,104, 105	Op Amp LM324
90	Op Amp LM662
91	Resistor 68 kohm
96, 103	Resistor 1 kohm
99	MC145041 A/D converter
110, 118	4081 B Gate
101, 108	12-7 kohm resistor
102, 106	1 meg ohm
109, 110, 111	Diode 1N4003
114	Capacitor 1.0 microfarad
140	Diode 1N4754
117	Circuit connection to Figure 4
119	Resistor 4-99 kohm
120	Resistor 6 kohm
121	Thermal cutoff
123	LED red.
124	Output to heater
125	Power into heater
126	Heater relay
127	Output to heater
128	Power into heater
129, 130	High limit relay
131, 132	Darlington relay drivers
133	Transistor 2N2222

FIG. 4

Reference	Description
25	Torroid 1/200
26	Torroid 1/1000
35	Computer
52	Relay D&B T90
53, 76	Diode 1N4003
54	Transistor 2N2222
55	Resistor 20K
56	Resistor 2K
57	Resistor 200 ohm
58	Capacitor 22 uf
59, 72	Capacitor .001 uf
60	Resistor 100 kohm
61	Resistor 220 kohm
62, 67	Resistor 260 kohm
63, 64, 69, 70	Diode 1N914
65	Operational amplifier 4M324
66	Capacitor 33 pf
68	Resistor 3.3 meg ohm
71	Capacitor 0.1 uf
73	Resistor 15K
74	Resistor 470 ohm
75	Capacitor .01 uf
150	Sense circuit

FIG. 5

Reference	Description
43	Neon bulb limiting resistor
44	Photo resistor
45	Circuit ground
46	+5 volts
42	Heater element
3	Heater assembly
50	Heater housing
36	Relays
16	Earth ground
28	Ground integrity detector housing
35	Microcomputer
20	Neon bulb

FIG. 6

Reference	Description
47	Bridge rectifier, 1 amp
48	Capacitor, 22 uf
49	Resistor, 10 kohm
50	Heater housing
51	Bleed resistor, 100 kohm
42	Heater element
3	Heater housing

36	Relay
30	Torroid 1/1,000 turns
16	Earth ground
34	Relay drivers
45	Circuit ground
35	Microcomputer
152	Sense circuit

FIG. 7A

Reference	Description
31	temperature sensor assembly
31A	sensor housing
31B	insulating bushing
142	potting compound
143	wire
144	wires

The embodiments shown are merely illustrative of the present invention. Many other examples of the embodiments set forth above and other modifications to the spa control system may be made without departing from the scope of this invention. It is understood that the details shown herein are to be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A heating and control system for bathers, comprising:

an electronic controller;

an electric heater assembly connected in a water flow path for heating water passing therethrough and comprising a heater housing and an electric heater element, the controller arranged to control the operation of the heater element, the heater assembly including a water conduit having a first port and a second port;

a water temperature sensor apparatus providing electrical temperature signals to the controller indicative of water temperature at separated first and second locations on or within said heater assembly or a combination thereof; and

a solid state water presence sensor apparatus to determine the presence or absence of water within said heater assembly, and to provide electrical water presence signals to the controller indicative of the presence or absence of a body of water within the heater assembly, said water presence sensor free of any moving parts in the flow path;

the controller responsive to signals from the water temperature sensor apparatus and the electrical water presence signals to control the heater assembly, said controller responsive to said electrical water presence signals indicating the absence of a body of water to disable operation of the heater assembly;

wherein the heater assembly may be connected in the water path in a first orientation with the water entering the first port and exiting the second port, or in a second orientation with water entering the second port and exiting the first port, with the water presence sensor operational with the heater assembly in the first orientation and with the heater assembly in the second orientation.

2. A system according to claim 1, wherein the controller includes means for selecting as an input temperature sensor location either the first location or the second location, in dependence on which sensor location reports a lower temperature value than the other sensor location as water is passing through the fluid conduit.

3. A spa system for bathers, comprising:

a vessel for holding a body of water;

a water heater assembly having a first input/output port and a second input/output port, the assembly connected in a water recirculation path coupled to the vessel;

a water presence sensor apparatus to determine the presence of water within the heater assembly and provide water presence signals indicative of the presence or absence of a body of water within the heater assembly;

a pump having an inlet port and an outlet port connected in the water recirculation path for recirculating water through said heater assembly and said vessel;

a water temperature sensor apparatus providing electrical temperature signals indicative of water temperature at separated first and second locations on or within said heater assembly, the sensor apparatus free of any moving parts within the water recirculation path;

the water heater assembly configured for connection in the water recirculation path either upstream of the pump inlet port or downstream of the pump outlet port, and with either the first input/output port or the second input/output port connected in the water recirculation path as the water heater inlet; and

an electronic controller for selectively activating and deactivating said pump at selected time intervals, said controller responsive to said temperature signals and said water presence signal to manage water parameters.

4. A spa system according to claim 3, wherein said controller is configured to disable operation of said heater in the absence of water within the heater assembly, and to automatically enable operation of the heater element upon subsequent receipt of water presence signals indicating the presence of a body of water within the heater housing.

5. A spa system of claim 4, wherein the controller is mounted on a circuit board attached to said water heater assembly.

6. A spa system of claim 3, wherein the controller includes means for selecting as an input temperature sensor location either the first location or the second location,

in dependence on which sensor location reports a lower temperature value than the other sensor location as water is passing through the fluid conduit.

7. A heater assembly for use in a bathing installation, comprising:

a heater housing defining a water conduit having a first port and a second port, wherein the first port and the second port are aligned along a linear heater axis;

an electrically actuated heater element for heating water passing through the heater housing; and

a water temperature sensor apparatus providing electrical temperature signals indicative of water temperature at separated first and second locations on or within said heater assembly or a combination thereof, said water temperature sensor apparatus comprising a first temperature sensor mounted to said housing near said first port and a second temperature sensor mounted to said housing near said second port.

8. The heater assembly of Claim 7, wherein the heater assembly may be connected in the water path in a first orientation with the water entering the first port and exiting the second port, or in a second orientation with water entering the second port and exiting the first port.

9. The heater assembly of Claim 7 or 8, wherein the heater housing is a metal housing.

10. The heater assembly of Claim 7 or 8, wherein the heater housing includes a plastic shell.

11. A heater assembly for use in a bathing installation, comprising:

a heater housing defining a water conduit having a first water port and a second water port, the first water port and the second water port arranged for connection in a water flow path of the bathing installation; and

an electrically actuated heater element for heating water passing through the heater housing, the heater housing having first and second sensor port openings formed therein to receive respective first and second temperature sensors providing electrical temperature signals indicative of temperature at separated first and second locations on or within said heater assembly, said first sensor port opening near said first port and said second sensor port opening near said second port;

wherein the heater assembly is further configured to be connected in the water flow path in a first orientation with the water entering the first port and exiting the second port, or in a second orientation with water entering the second port and exiting the first port.

12. The heater assembly of Claim 11, wherein the heater housing is a metal housing.

13. The heater assembly of Claim 11, wherein the heater housing includes a plastic shell.

14. The heater assembly of any one of claims 11 to 13, further comprising:

a first temperature sensor configured for engagement into said first sensor port; and

a second temperature sensor configured for engagement into said second sensor port.

15. The heater assembly of any one of claims 11 to 14, wherein the first and second sensor ports are threaded to receive respective the respective first and second sensors.

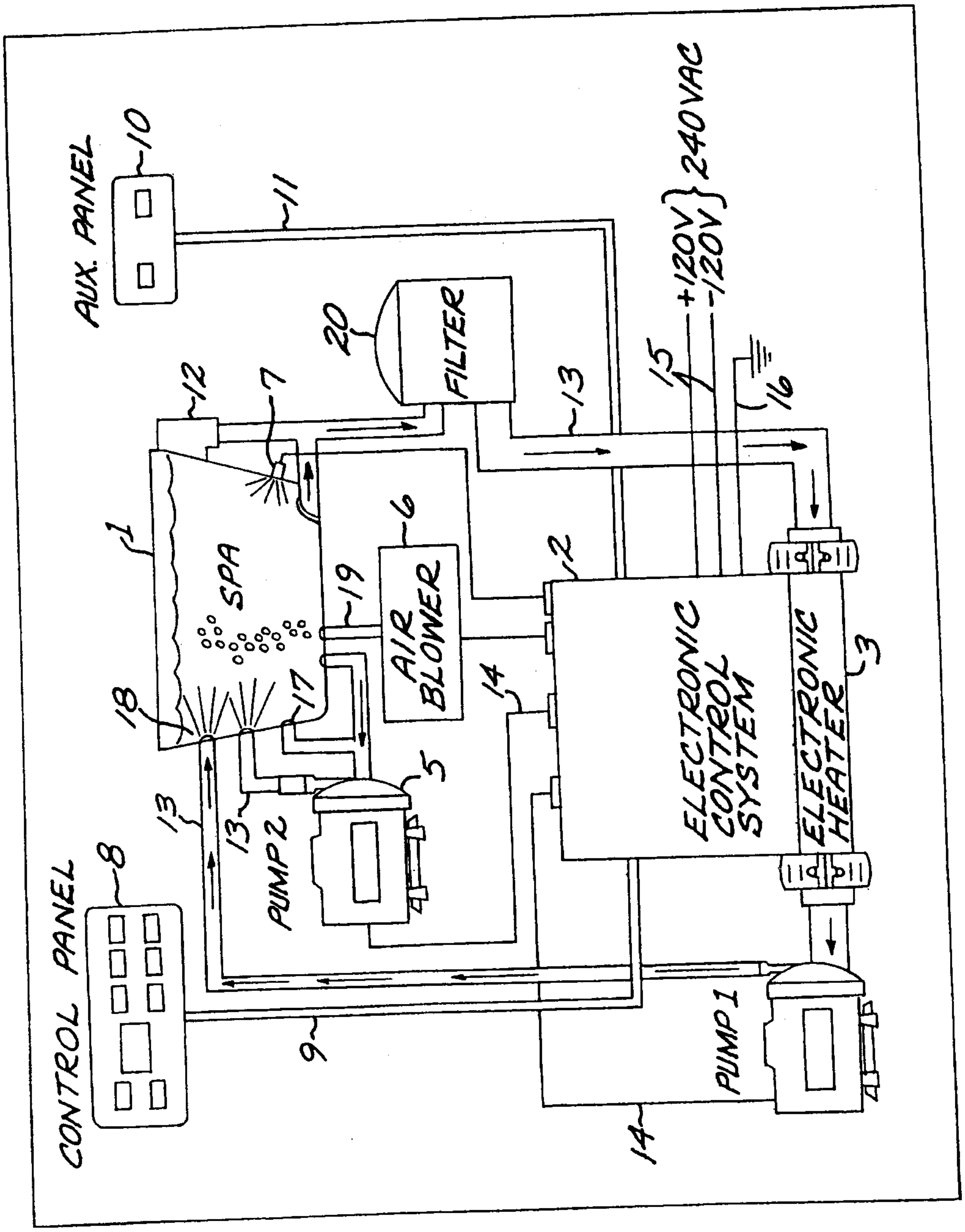

CONTROL PANEL
8
AUX. PANEL
10
11
FILTER
20
SPA
1
AIR BLOWER
6
ELECTRONIC CONTROL SYSTEM
ELECTRONIC HEATER
3
PUMP 1
PUMP 2
5
+120V
-120V
240VAC
2
7
9
12
13
14
15
16
17
18
19

FIG. 1

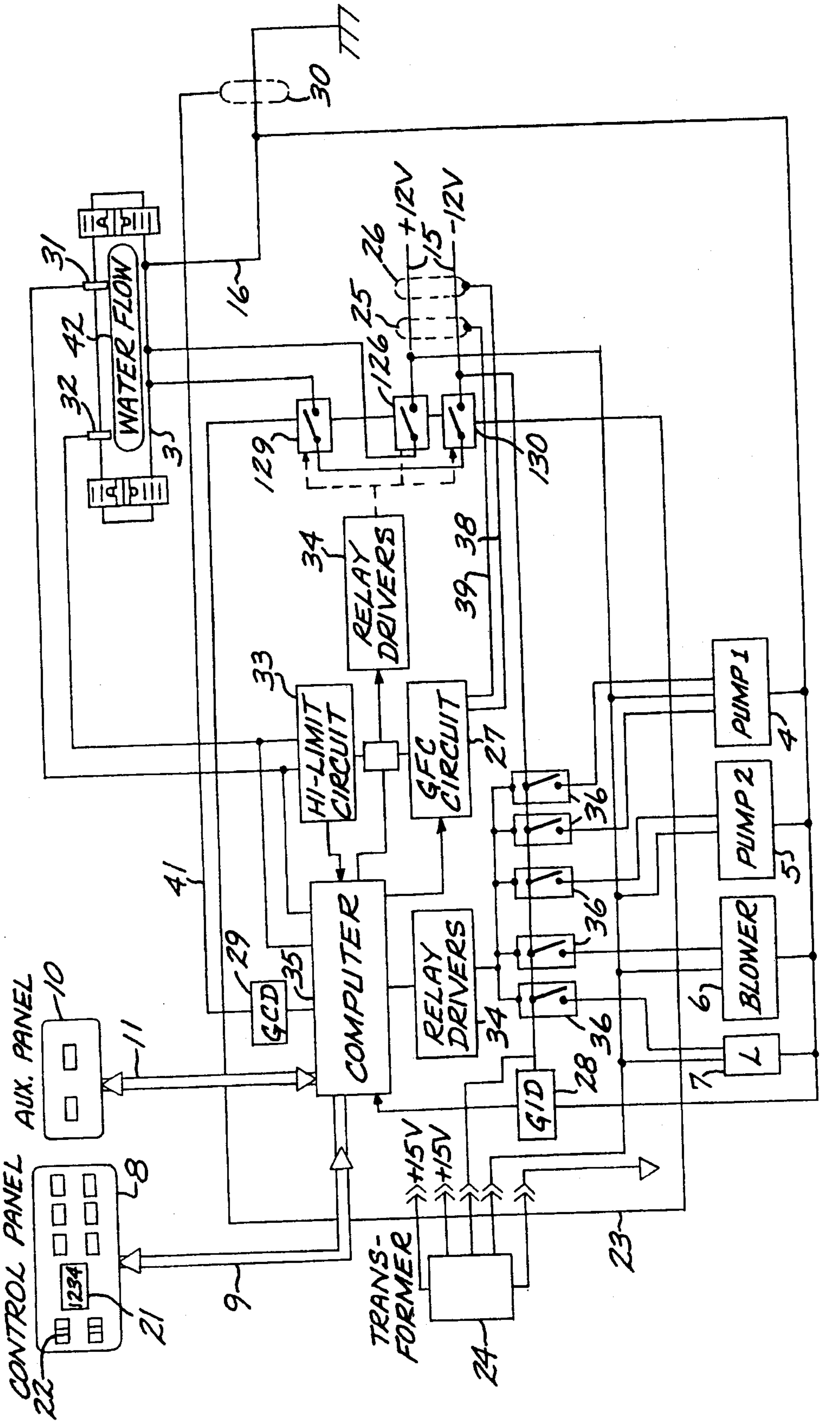

CONTROL PANEL
AUX. PANEL
COMPUTER
GCD
RELAY DRIVERS
HI-LIMIT CIRCUIT
GFC CIRCUIT
WATER FLOW
PUMP 1
PUMP 2
BLOWER
L
G/D
TRANS-FORMER
+15V
+12V
-12V
1234

FIG.2A

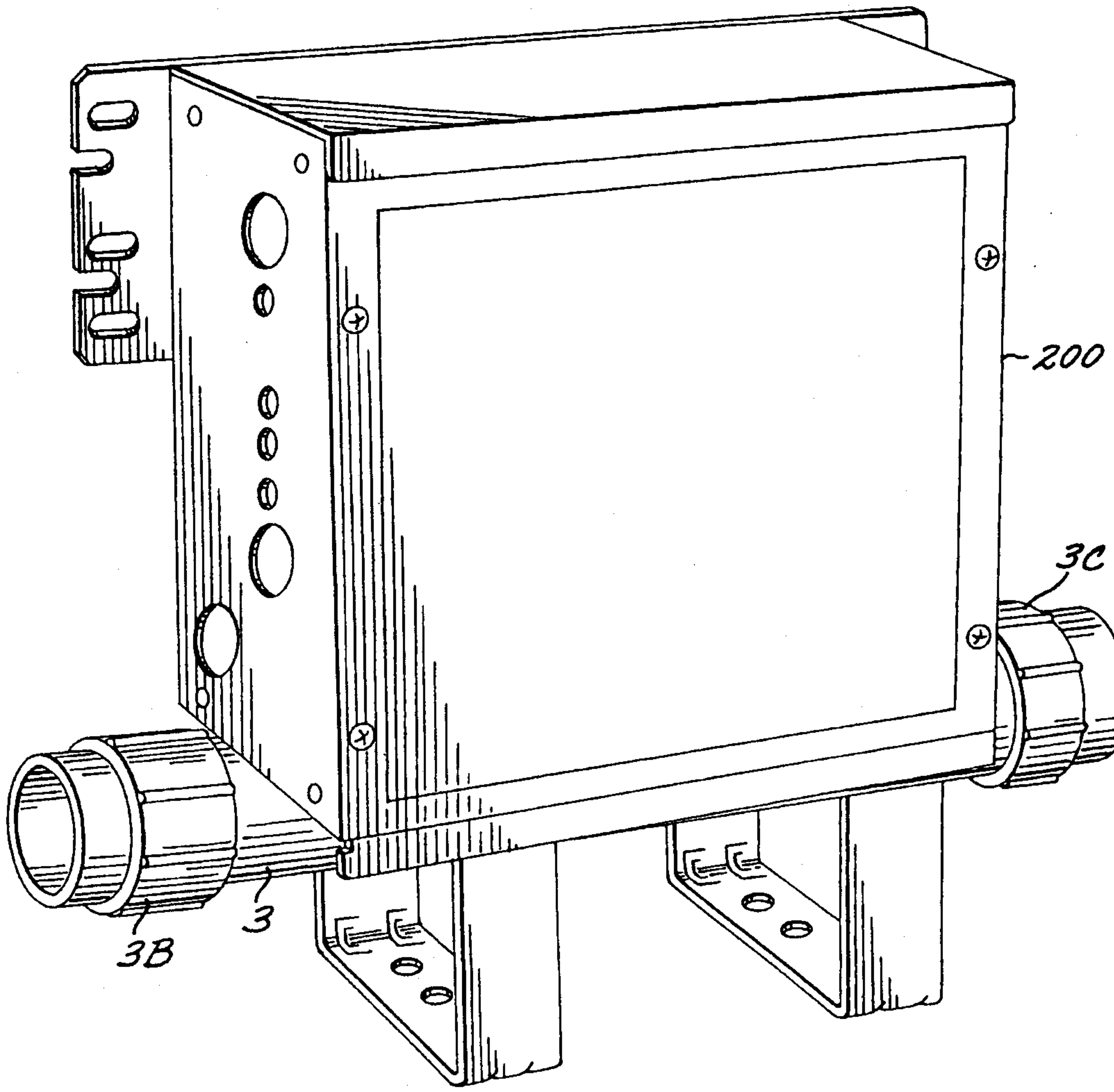


FIG. 2B

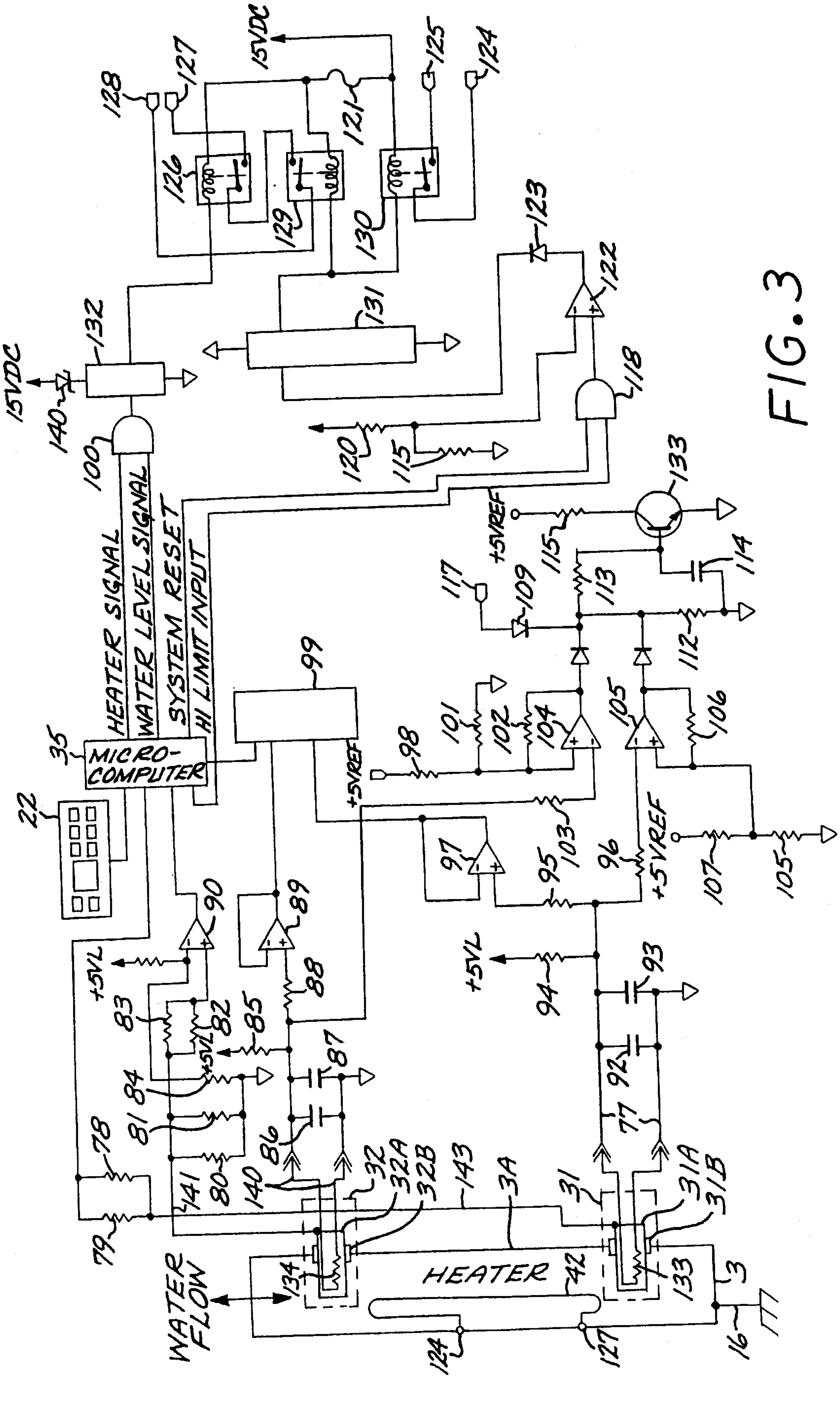

HEATER SIGNAL
WATER LEVEL SIGNAL
SYSTEM RESET
HI LIMIT INPUT
MICRO-COMPUTER
15VDC
+5VREF
+5VL
HEATER
WATER FLOW

FIG.3

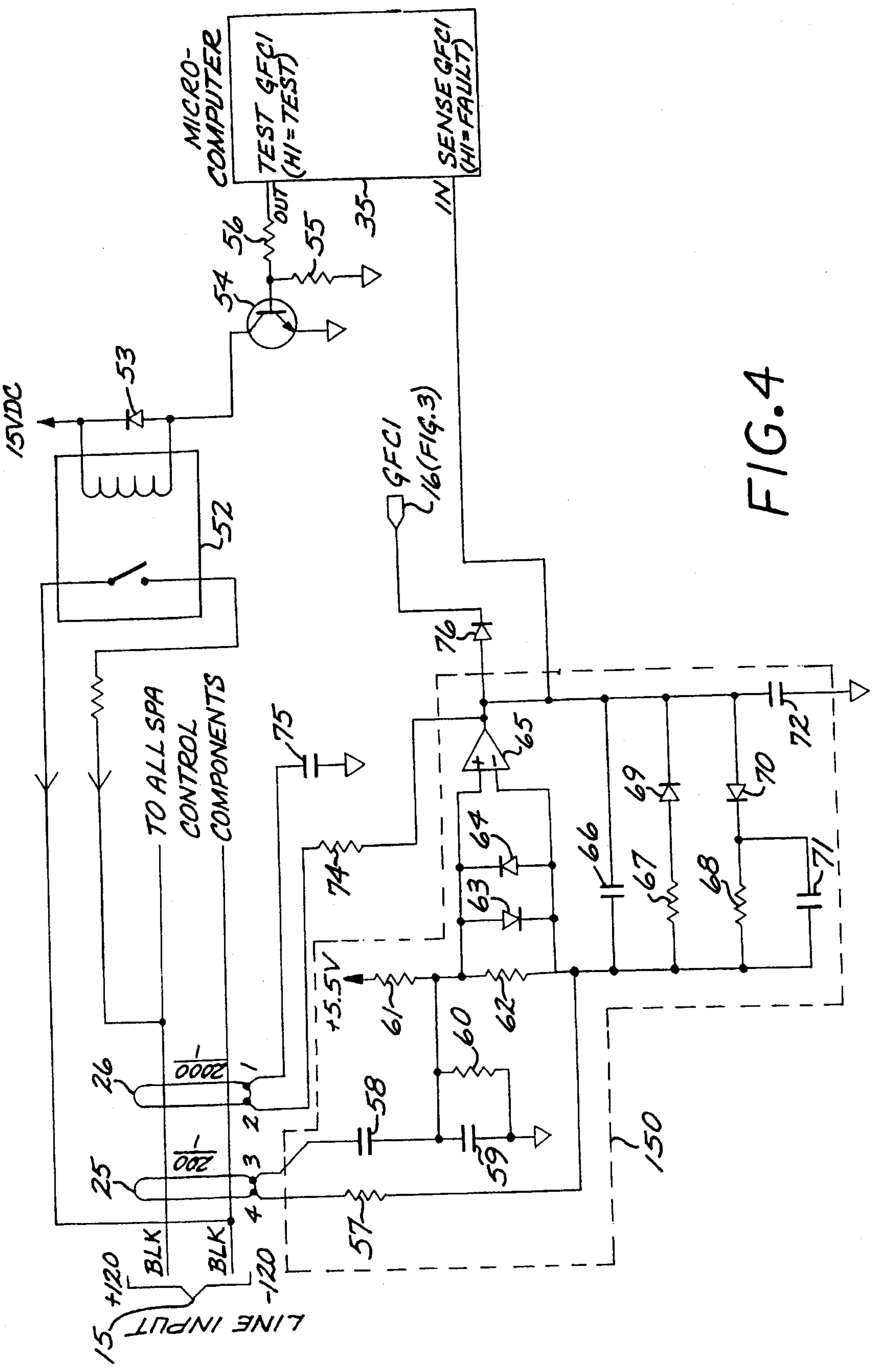

MICRO-COMPUTER
TEST GFCI (HI=TEST)
SENSE GFCI (HI=FAULT)
OUT
IN
35
56
55
54
53
15VDC
52
GFCI 16 (FIG.3)
76
65
72
69
70
66
67
68
71
63
64
74
75
TO ALL SPA CONTROL COMPONENTS
+5.5V
61
62
60
58
59
57
150
26
25
1/2000
1/200
1
2
3
4
BLK
BLK
+120
-120
LINE INPUT
15

FIG.4

FIG. 5

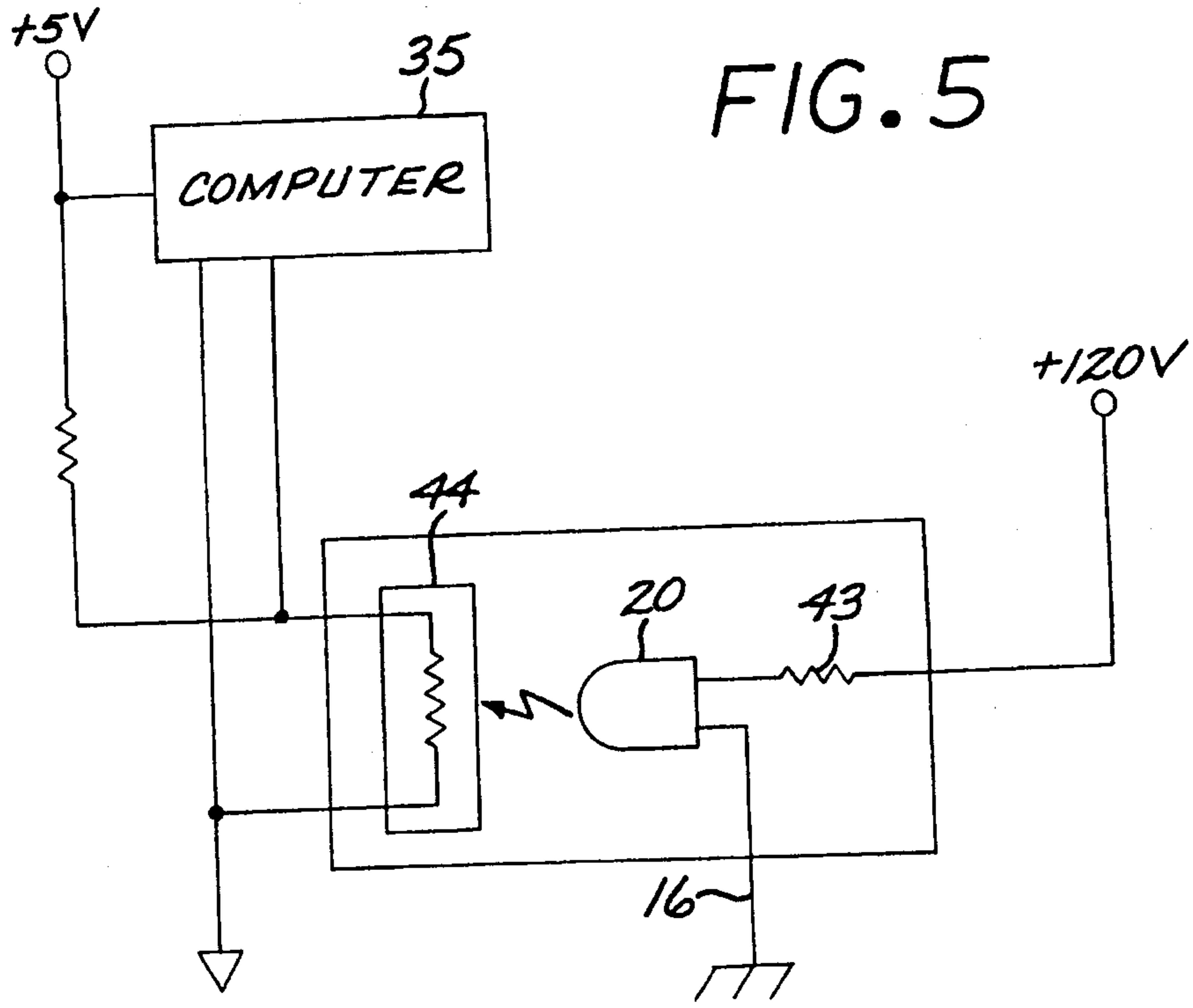
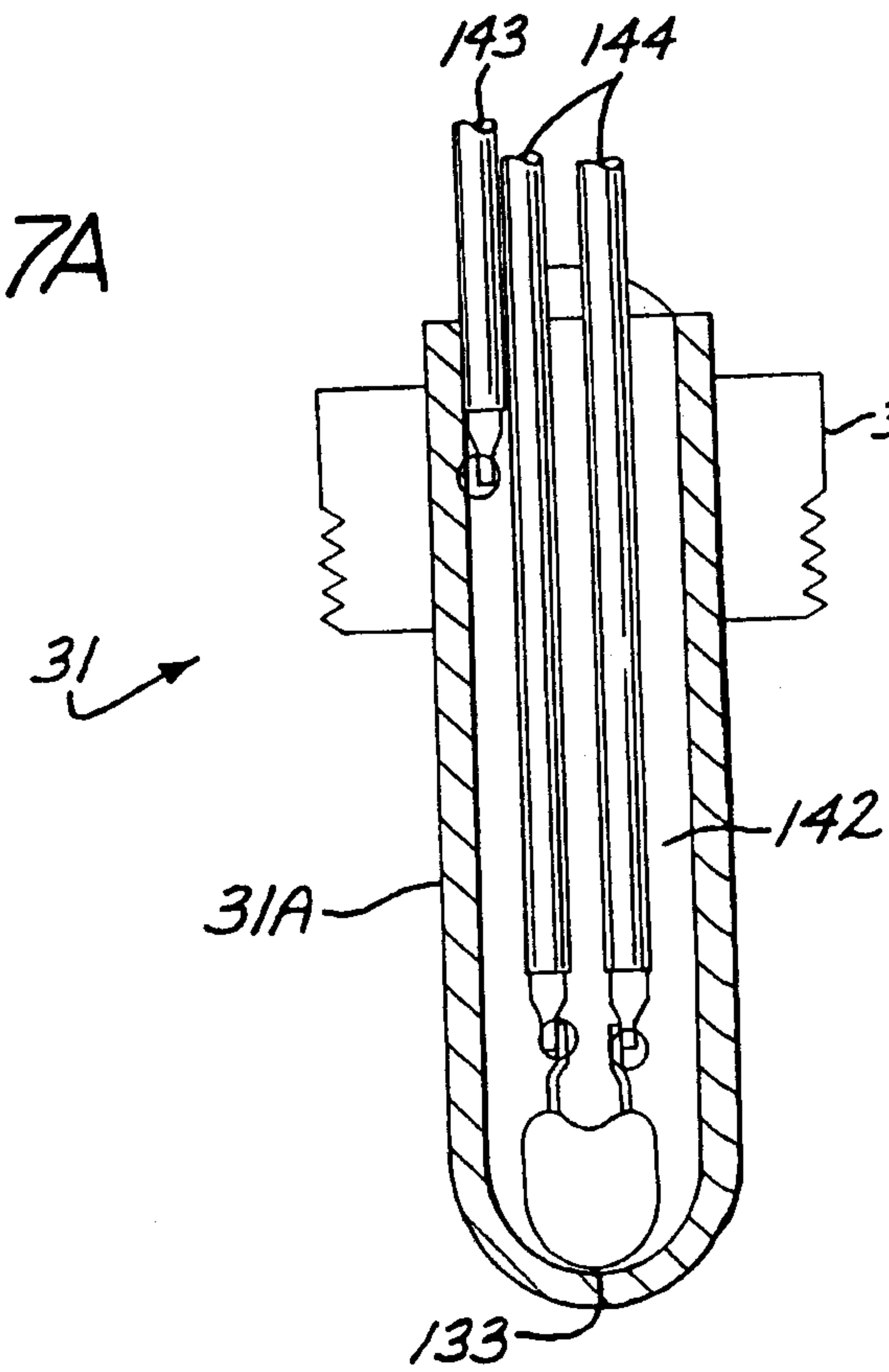
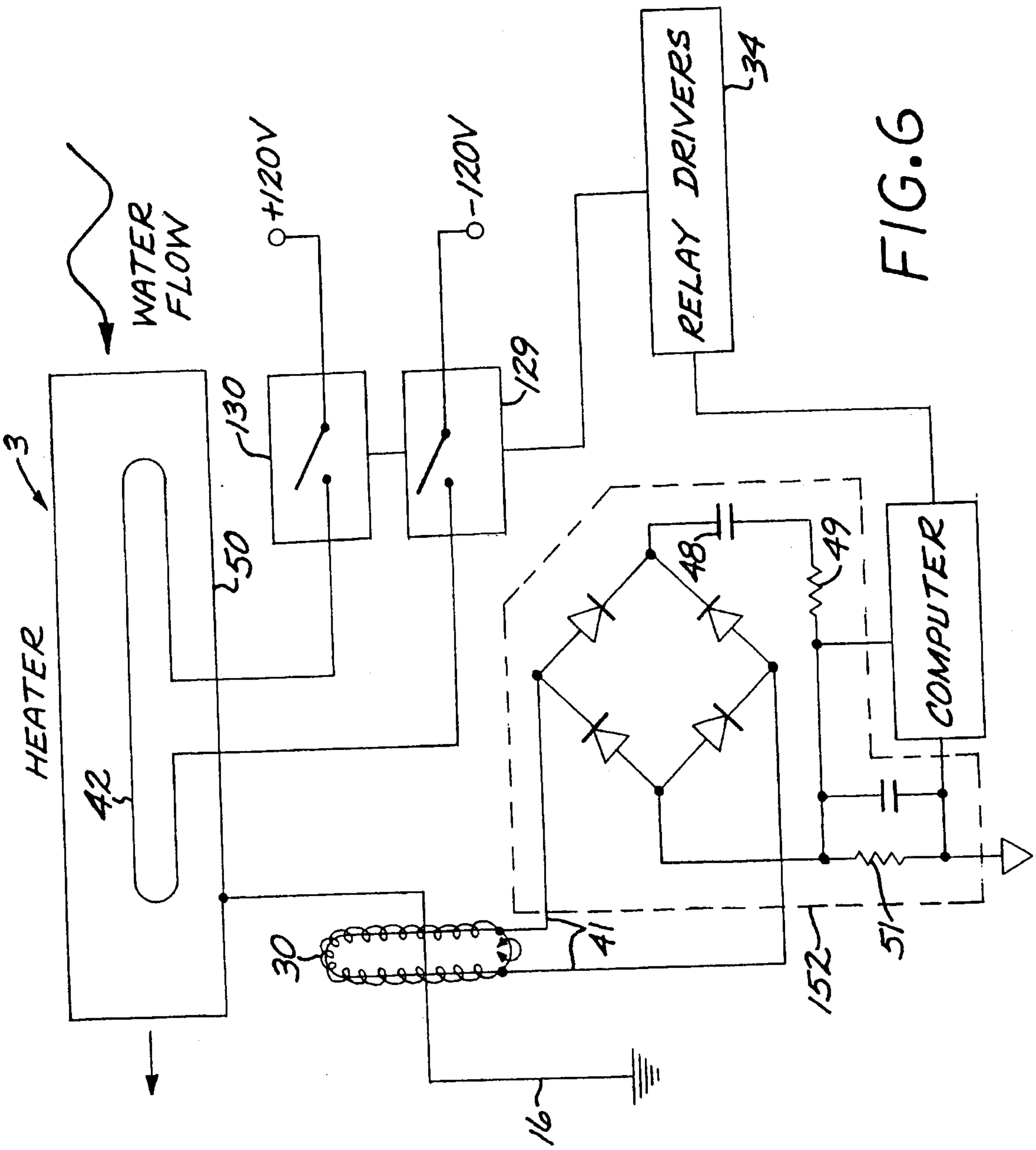


FIG. 7A





WATER FLOW
+120V
-120V
RELAY DRIVERS
34
3
130
129
HEATER
42
50
48
49
COMPUTER
30
41
152
51
16

FIG.6

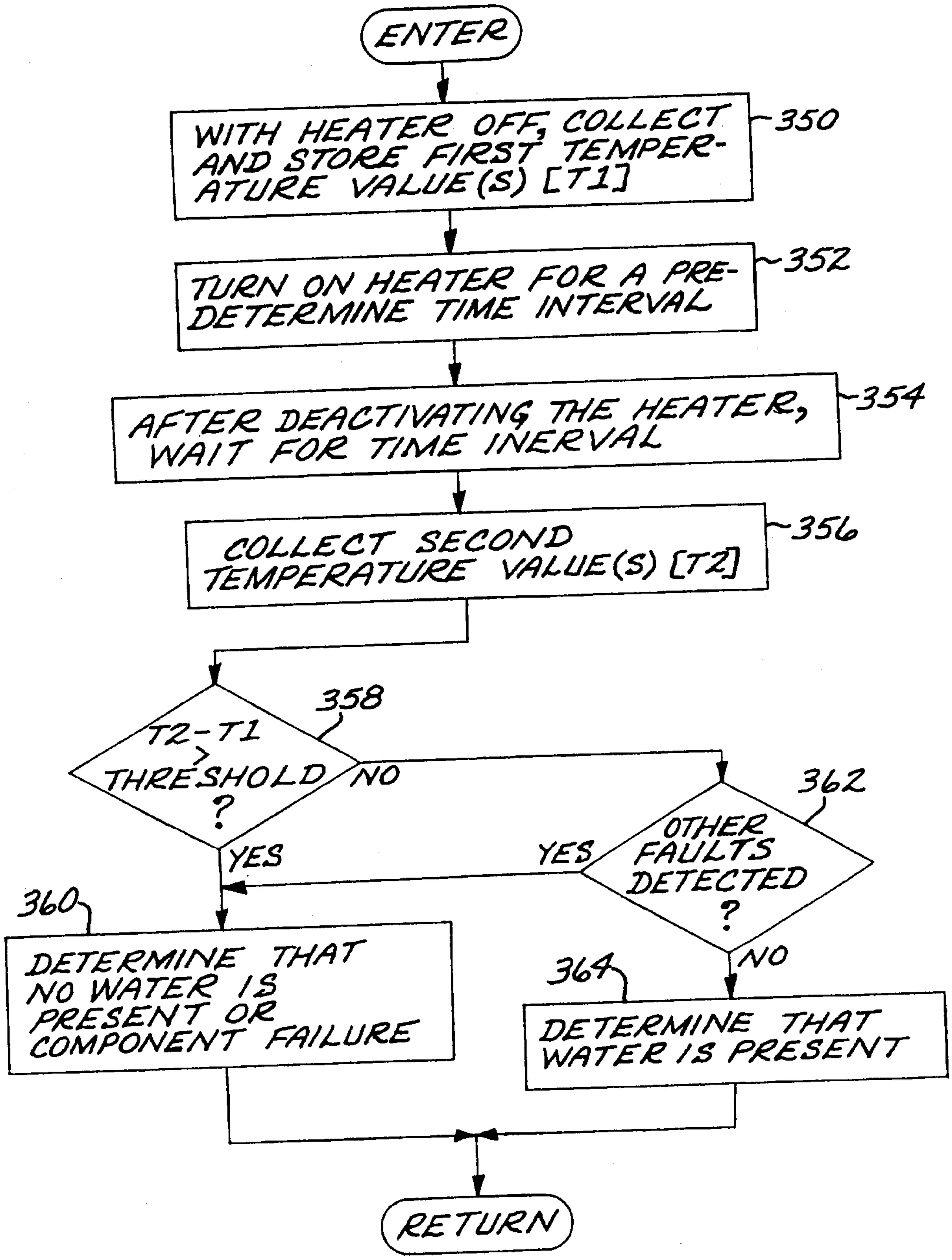

ENTER
WITH HEATER OFF, COLLECT AND STORE FIRST TEMPERATURE VALUE(S) [T1]
350
TURN ON HEATER FOR A PREDETERMINE TIME INTERVAL
352
AFTER DEACTIVATING THE HEATER, WAIT FOR TIME INERVAL
354
COLLECT SECOND TEMPERATURE VALUE(S) [T2]
356
T2-T1 > THRESHOLD ?
358
NO
YES
OTHER FAULTS DETECTED ?
362
YES
NO
360
DETERMINE THAT NO WATER IS PRESENT OR COMPONENT FAILURE
364
DETERMINE THAT WATER IS PRESENT
RETURN

FIG.7B

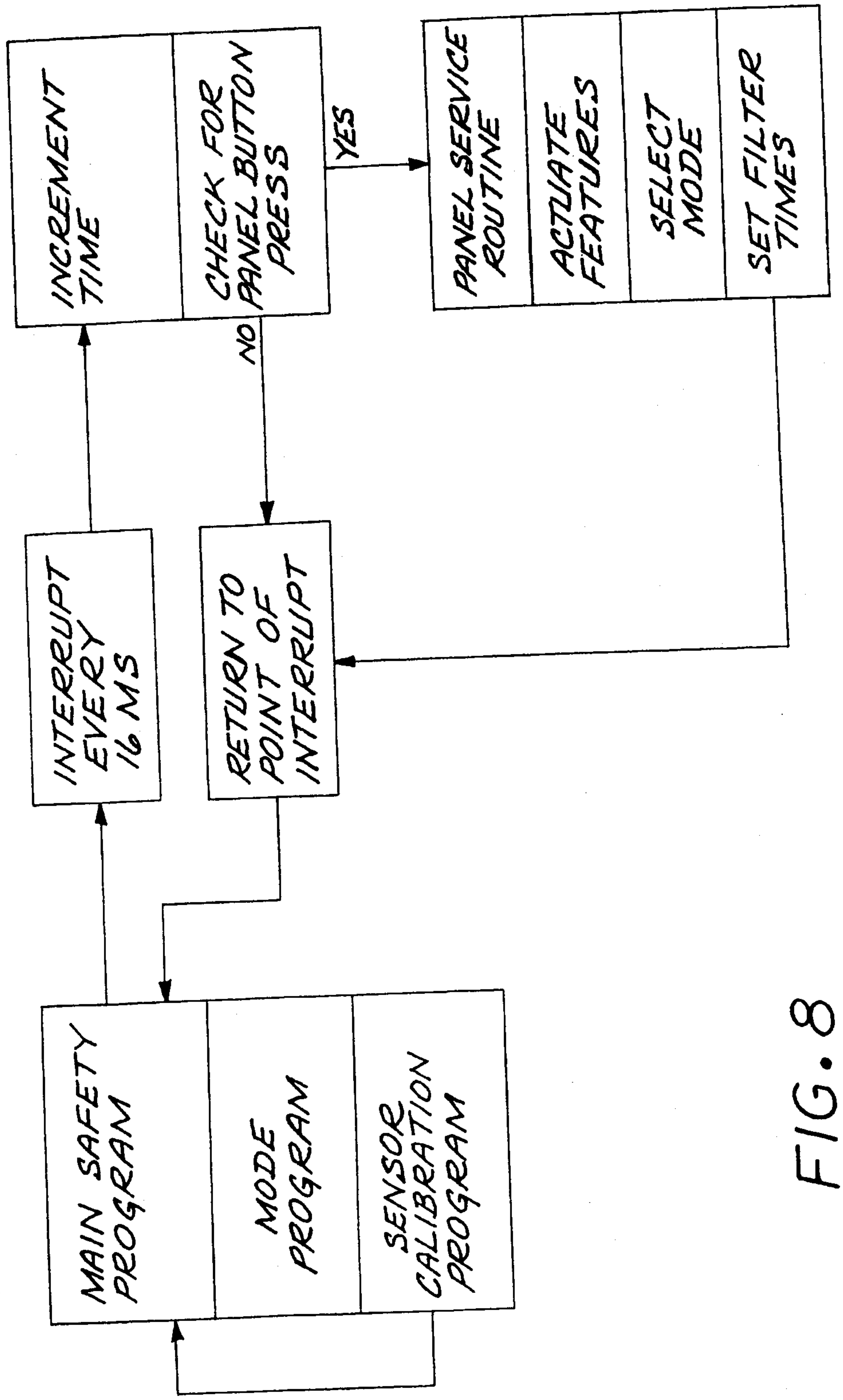

INCREMENT TIME
CHECK FOR PANEL BUTTON PRESS
YES
NO
PANEL SERVICE ROUTINE
ACTUATE FEATURES
SELECT MODE
SET FILTER TIMES
INTERRUPT EVERY 16 MS
RETURN TO POINT OF INTERRUPT
MAIN SAFETY PROGRAM
MODE PROGRAM
SENSOR CALIBRATION PROGRAM

FIG. 8

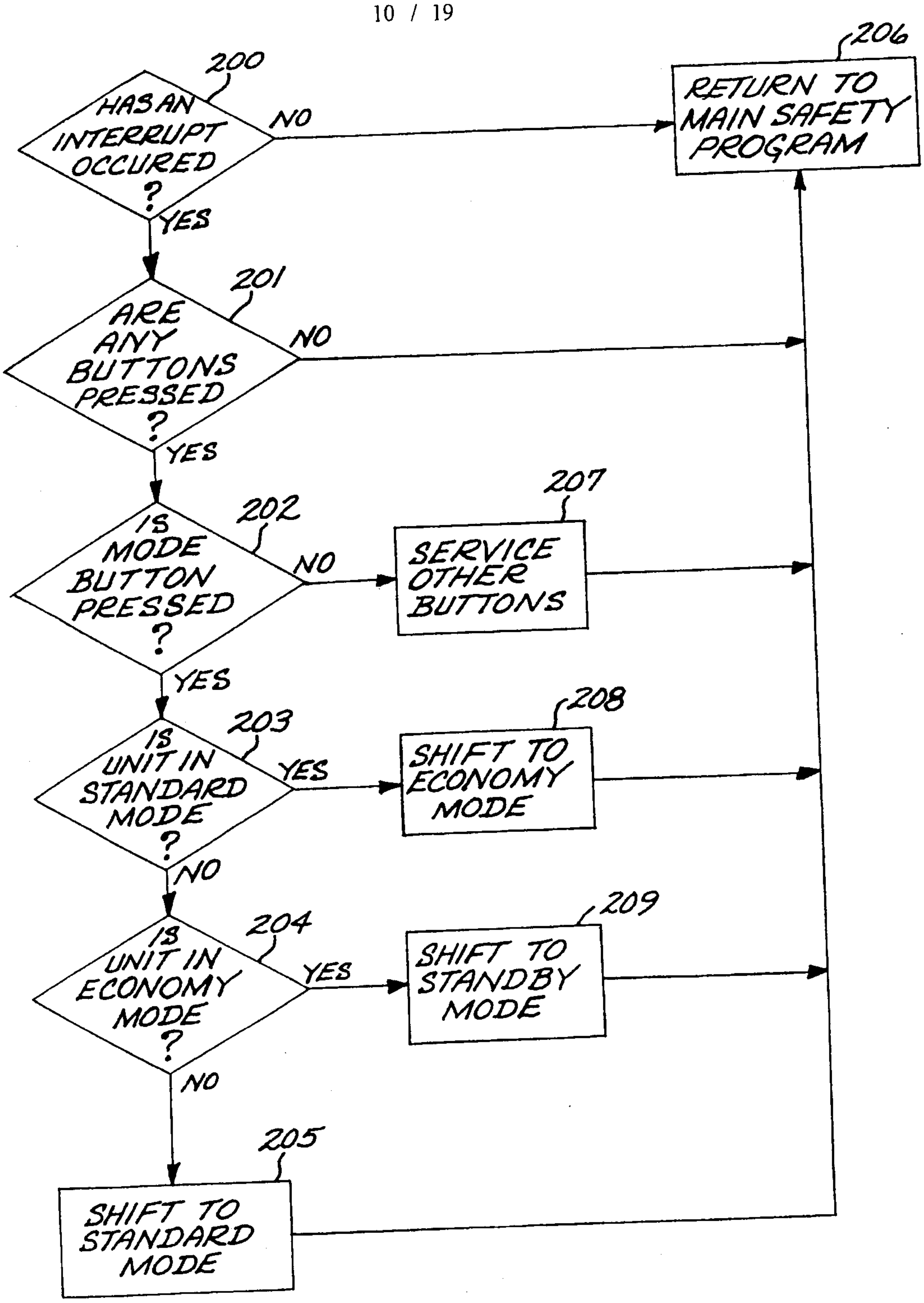

200
HAS AN INTERRUPT OCCURED ?
NO
YES
206
RETURN TO MAIN SAFETY PROGRAM
201
ARE ANY BUTTONS PRESSED ?
NO
YES
202
IS MODE BUTTON PRESSED ?
NO
207
SERVICE OTHER BUTTONS
YES
203
IS UNIT IN STANDARD MODE ?
YES
208
SHIFT TO ECONOMY MODE
NO
204
IS UNIT IN ECONOMY MODE ?
YES
209
SHIFT TO STANDBY MODE
NO
205
SHIFT TO STANDARD MODE

FIG.9

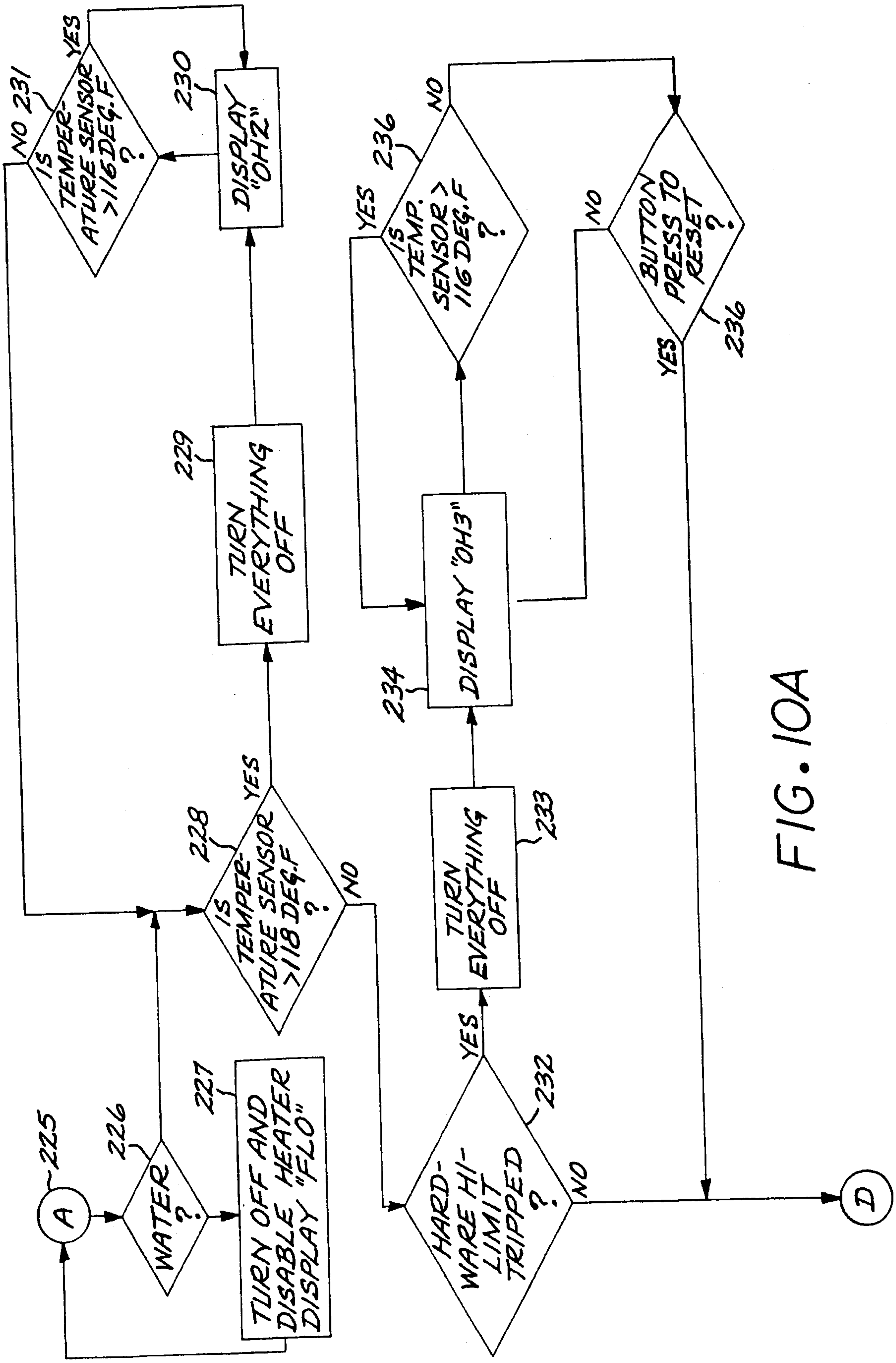

225
A
226
WATER ?
227
TURN OFF AND DISABLE HEATER DISPLAY "FLO"
228
IS TEMPERATURE SENSOR >118 DEG.F ?
YES
NO
229
TURN EVERYTHING OFF
230
DISPLAY "OH2"
231
IS TEMPERATURE SENSOR >116 DEG.F ?
YES
NO
232
HARDWARE HI-LIMIT TRIPPED ?
YES
NO
233
TURN EVERYTHING OFF
234
DISPLAY "OH3"
236
IS TEMP. SENSOR > 116 DEG.F ?
YES
NO
236
BUTTON PRESS TO RESET ?
YES
NO
D

FIG. 10A

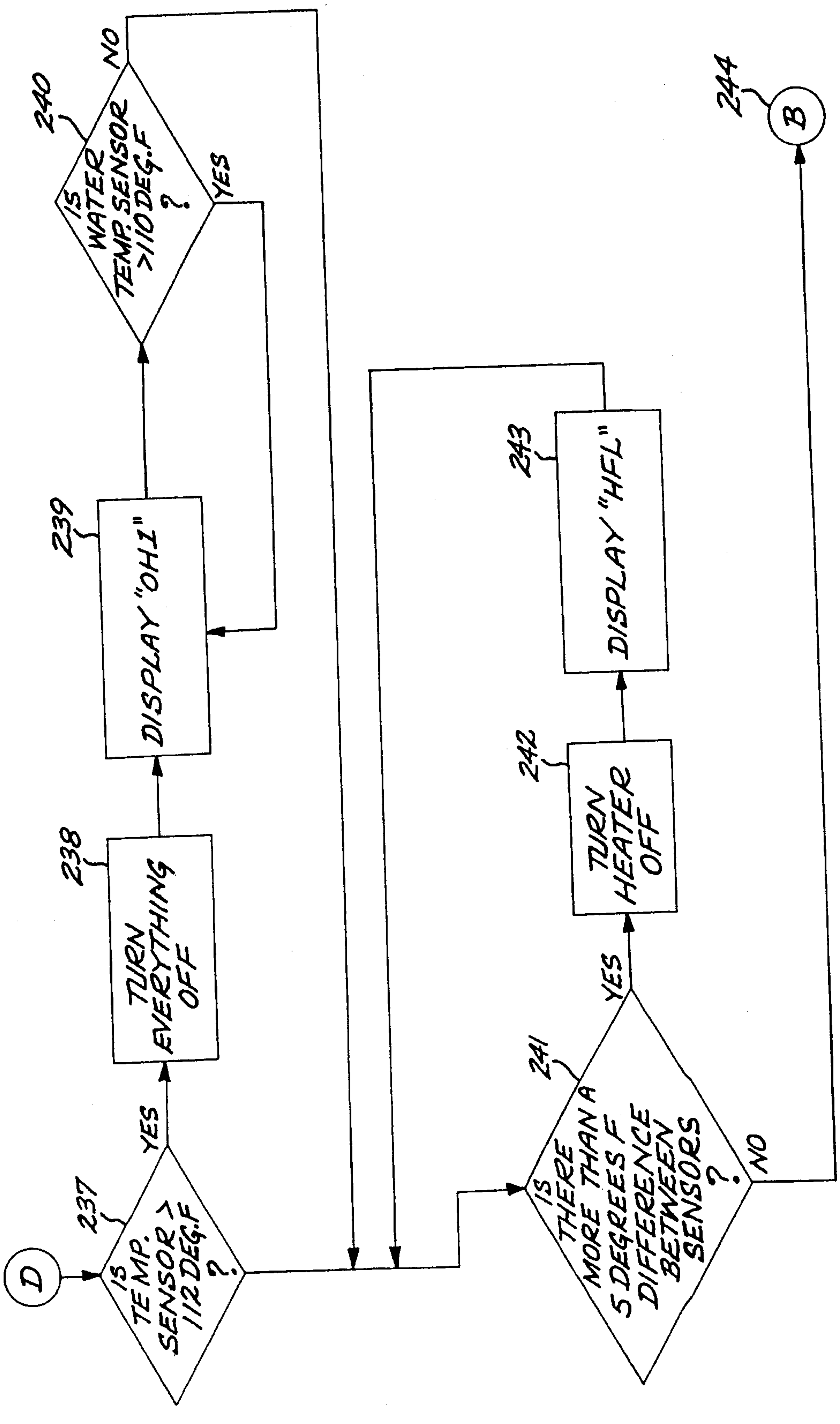

D
237
IS TEMP. SENSOR > 112 DEG.F ?
YES
238
TURN EVERYTHING OFF
239
DISPLAY "OHI"
240
IS WATER TEMP. SENSOR >110 DEG.F ?
YES
NO
241
IS THERE MORE THAN A 5 DEGREES F DIFFERENCE BETWEEN SENSORS ?
YES
NO
242
TURN HEATER OFF
243
DISPLAY "HFL"
244
B

FIG. 10B

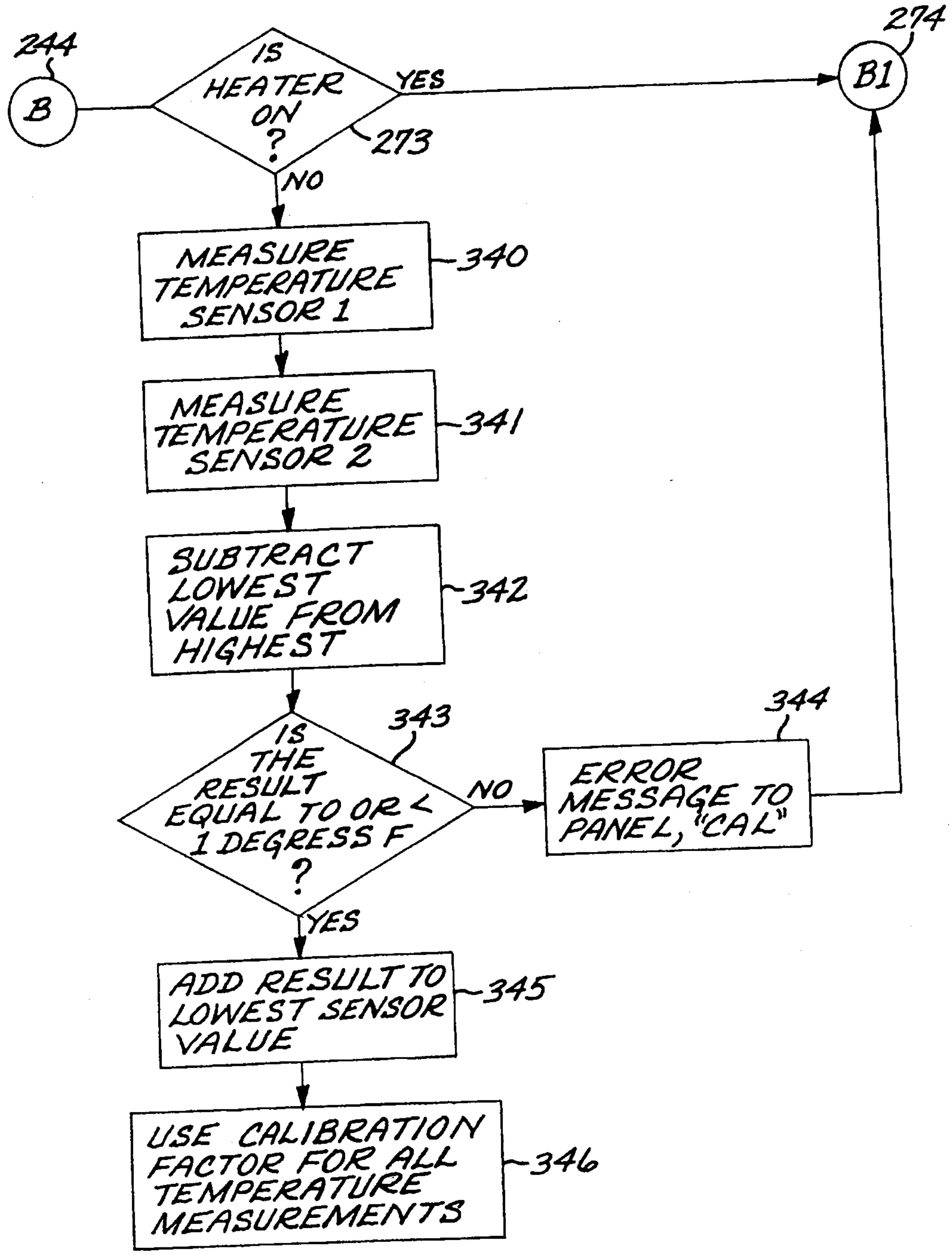

244
B
IS HEATER ON ?
YES
273
274
B1
NO
MEASURE TEMPERATURE SENSOR 1
340
MEASURE TEMPERATURE SENSOR 2
341
SUBTRACT LOWEST VALUE FROM HIGHEST
342
343
IS THE RESULT EQUAL TO OR < 1 DEGRESS F ?
NO
344
ERROR MESSAGE TO PANEL, "CAL"
YES
ADD RESULT TO LOWEST SENSOR VALUE
345
USE CALIBRATION FACTOR FOR ALL TEMPERATURE MEASUREMENTS
346

FIG. 11

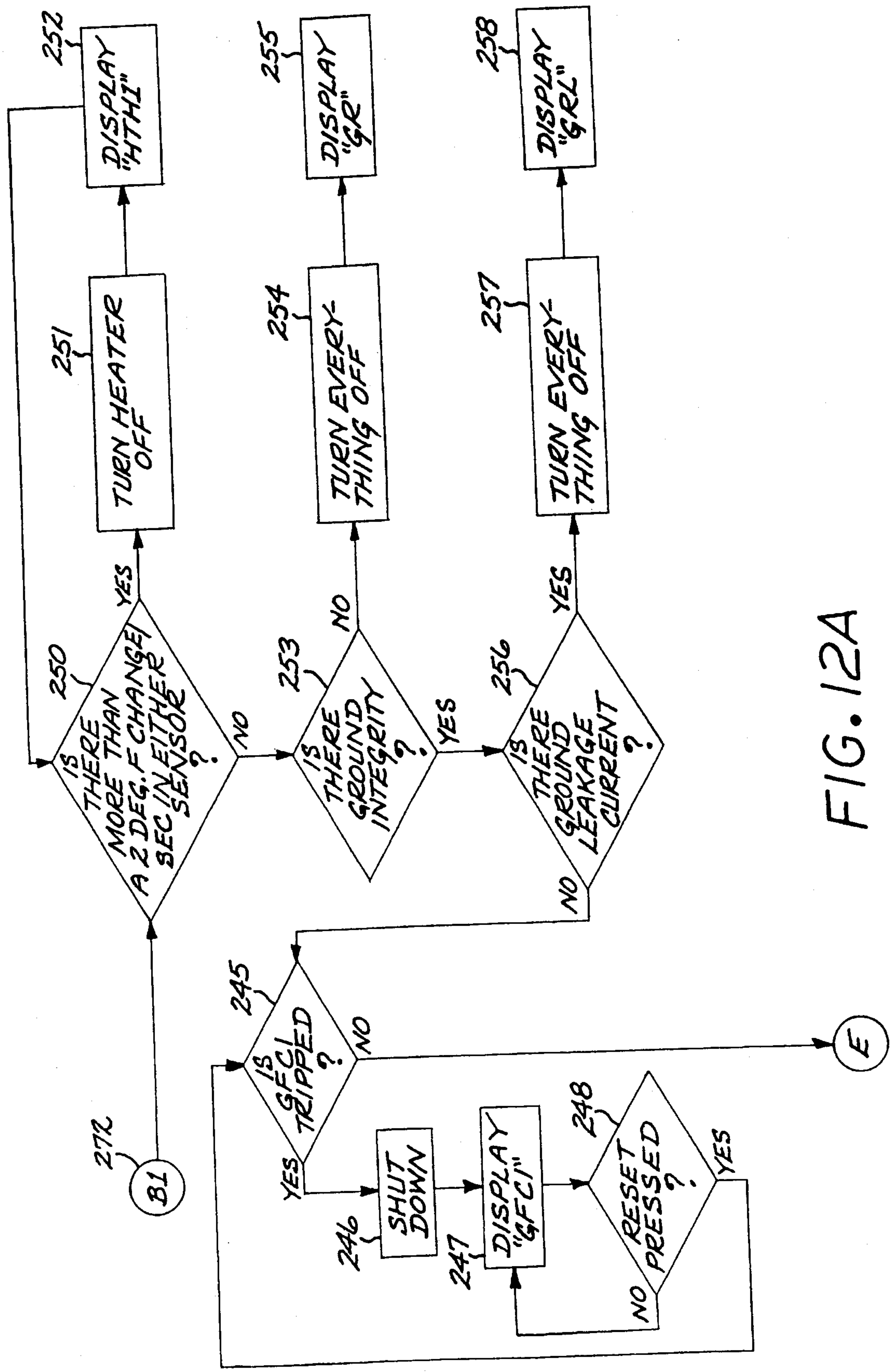

272
B1
250
IS THERE MORE THAN A 2 DEG. F CHANGE/ SEC IN EITHER SENSOR ?
YES
NO
251
TURN HEATER OFF
252
DISPLAY "HTHI"
253
IS THERE GROUND INTEGRITY ?
NO
YES
254
TURN EVERY-THING OFF
255
DISPLAY "GR"
256
IS THERE GROUND LEAKAGE CURRENT ?
YES
NO
257
TURN EVERY-THING OFF
258
DISPLAY "GRL"
245
IS GFCI TRIPPED ?
NO
YES
E
246
SHUT DOWN
247
DISPLAY "GFCI"
248
RESET PRESSED ?
YES
NO

FIG. 12A

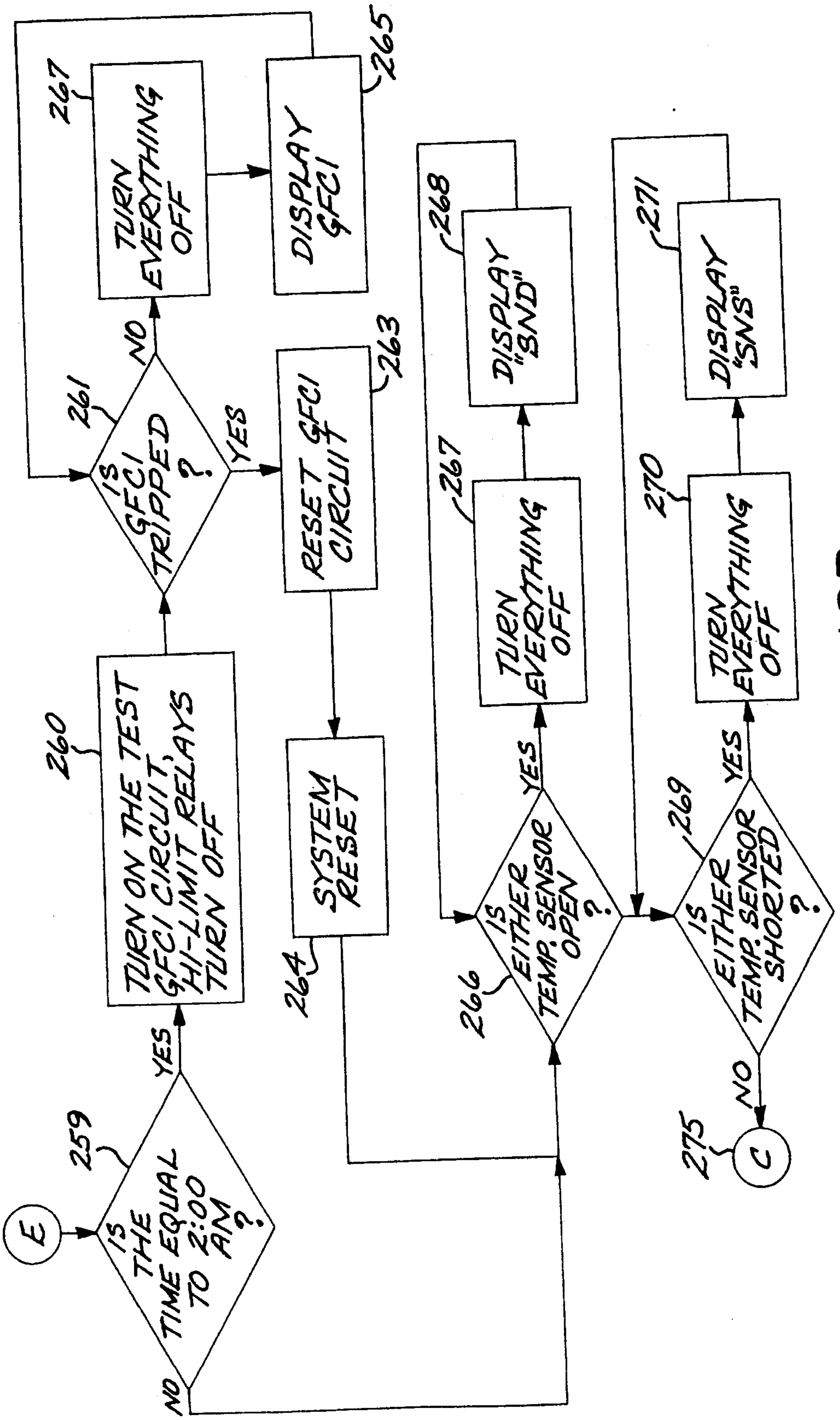
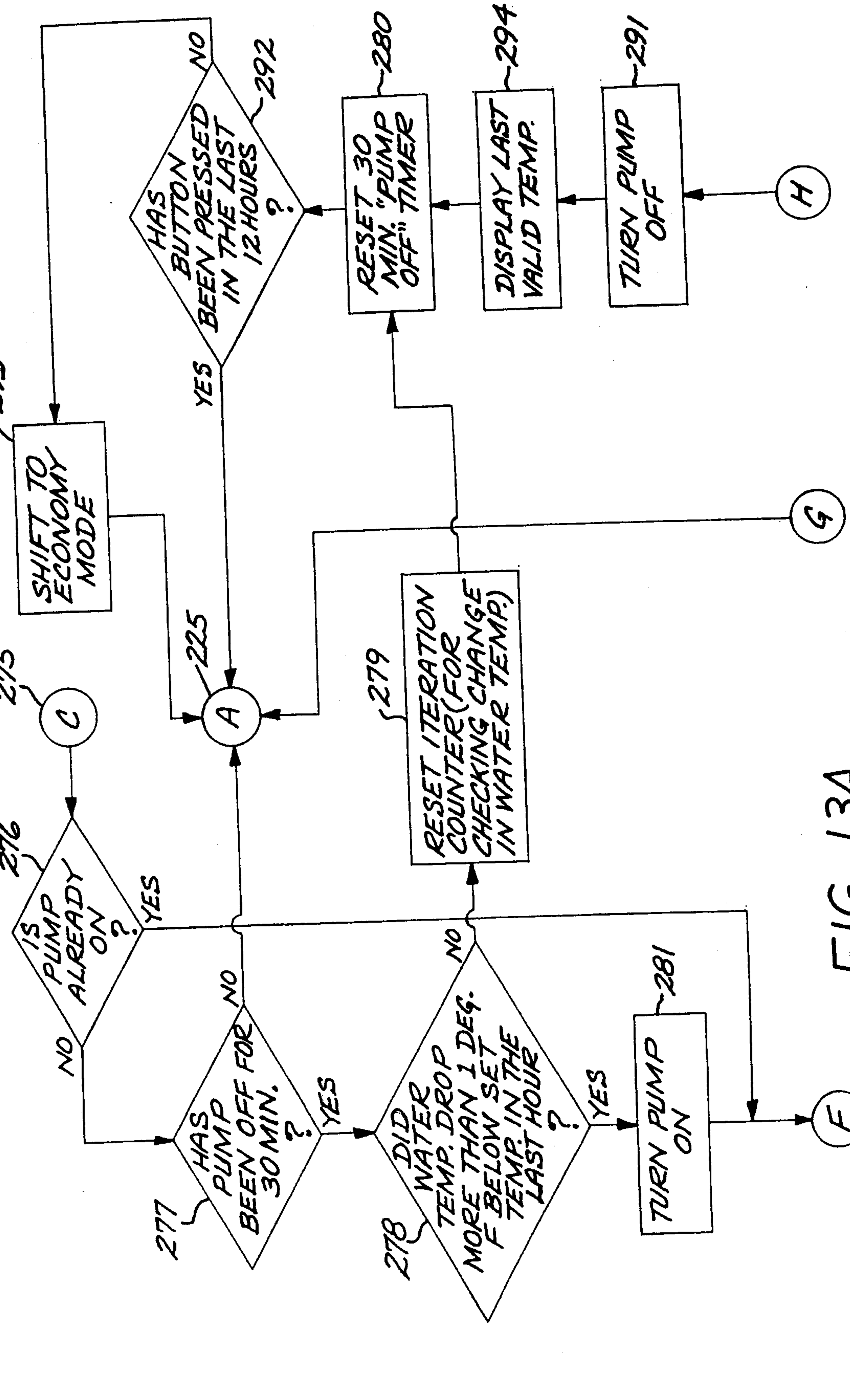

E
259
IS THE TIME EQUAL TO 2:00 AM ?
NO
YES
260
TURN ON THE TEST GFCI CIRCUIT, HI-LIMIT RELAYS TURN OFF
261
IS GFCI TRIPPED ?
NO
YES
267
TURN EVERYTHING OFF
265
DISPLAY GFCI
263
RESET GFCI CIRCUIT
264
SYSTEM RESET
266
IS EITHER TEMP. SENSOR OPEN ?
YES
267
TURN EVERYTHING OFF
268
DISPLAY "SND"
269
IS EITHER TEMP. SENSOR SHORTED ?
YES
NO
270
TURN EVERYTHING OFF
271
DISPLAY "SNS"
275
C

FIG. 12B



HAS BUTTON BEEN PRESSED IN THE LAST 12 HOURS ?
292
NO
YES
SHIFT TO ECONOMY MODE
293
RESET 30 MIN. "PUMP OFF" TIMER
280
DISPLAY LAST VALID TEMP.
294
TURN PUMP OFF
291
H
G
A
225
C
275
IS PUMP ALREADY ON ?
276
YES
NO
HAS PUMP BEEN OFF FOR 30 MIN. ?
277
NO
YES
RESET ITERATION COUNTER (FOR CHECKING CHANGE IN WATER TEMP.)
279
DID WATER TEMP. DROP MORE THAN 1 DEG. F BELOW SET TEMP. IN THE LAST HOUR ?
278
NO
YES
TURN PUMP ON
281
F

FIG. 13A

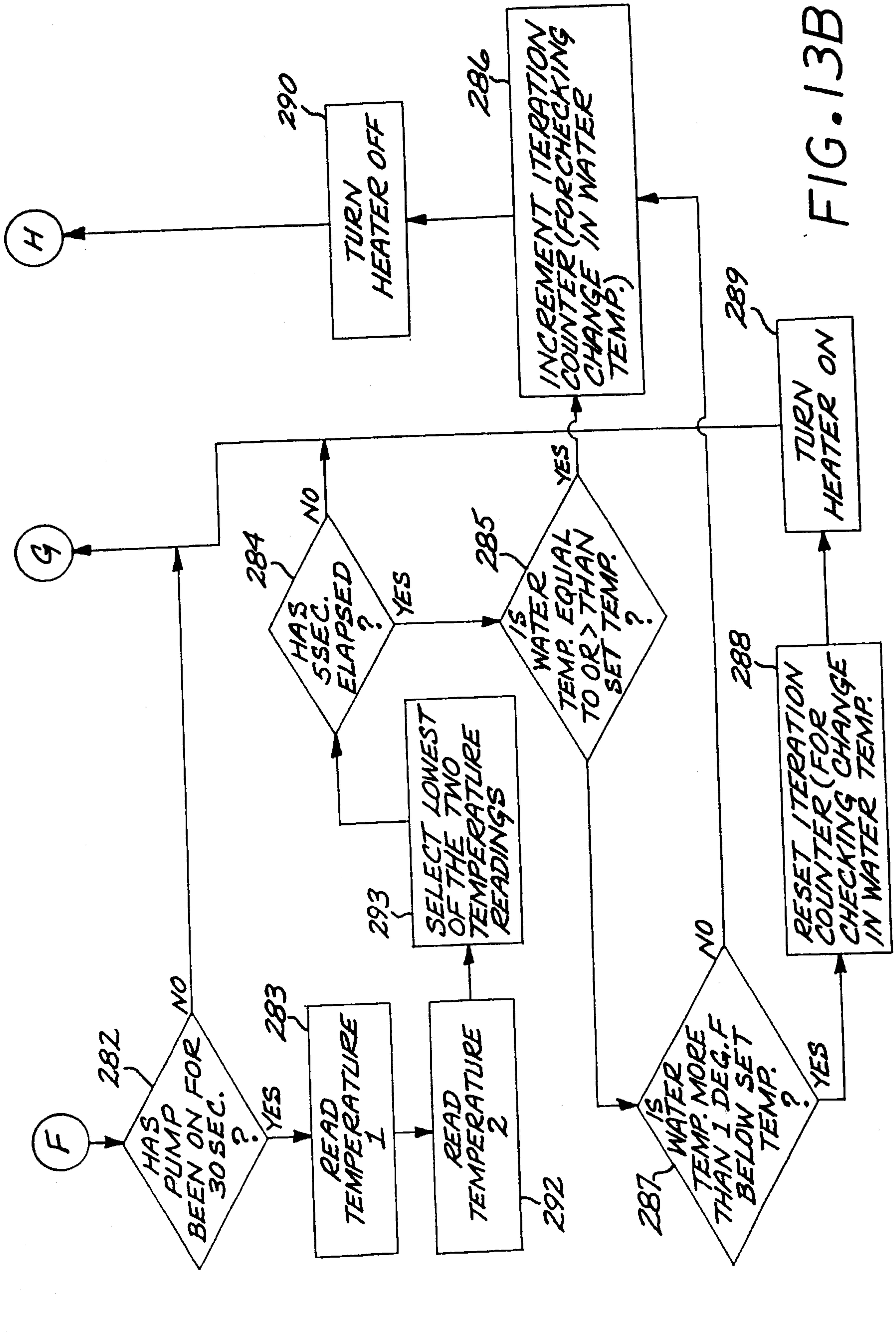

F
HAS PUMP BEEN ON FOR 30 SEC. ?
282
YES
NO
READ TEMPERATURE 1
283
READ TEMPERATURE 2
292
SELECT LOWEST OF THE TWO TEMPERATURE READINGS
293
HAS 5SEC. ELAPSED ?
284
YES
NO
IS WATER TEMP. EQUAL TO OR > THAN SET TEMP. ?
285
YES
NO
INCREMENT ITERATION COUNTER (FOR CHECKING CHANGE IN WATER TEMP.)
286
TURN HEATER OFF
290
H
G
IS WATER TEMP. MORE THAN 1 DEG.F BELOW SET TEMP. ?
287
YES
NO
RESET ITERATION COUNTER (FOR CHECKING CHANGE IN WATER TEMP.
288
TURN HEATER ON
289

FIG.13B

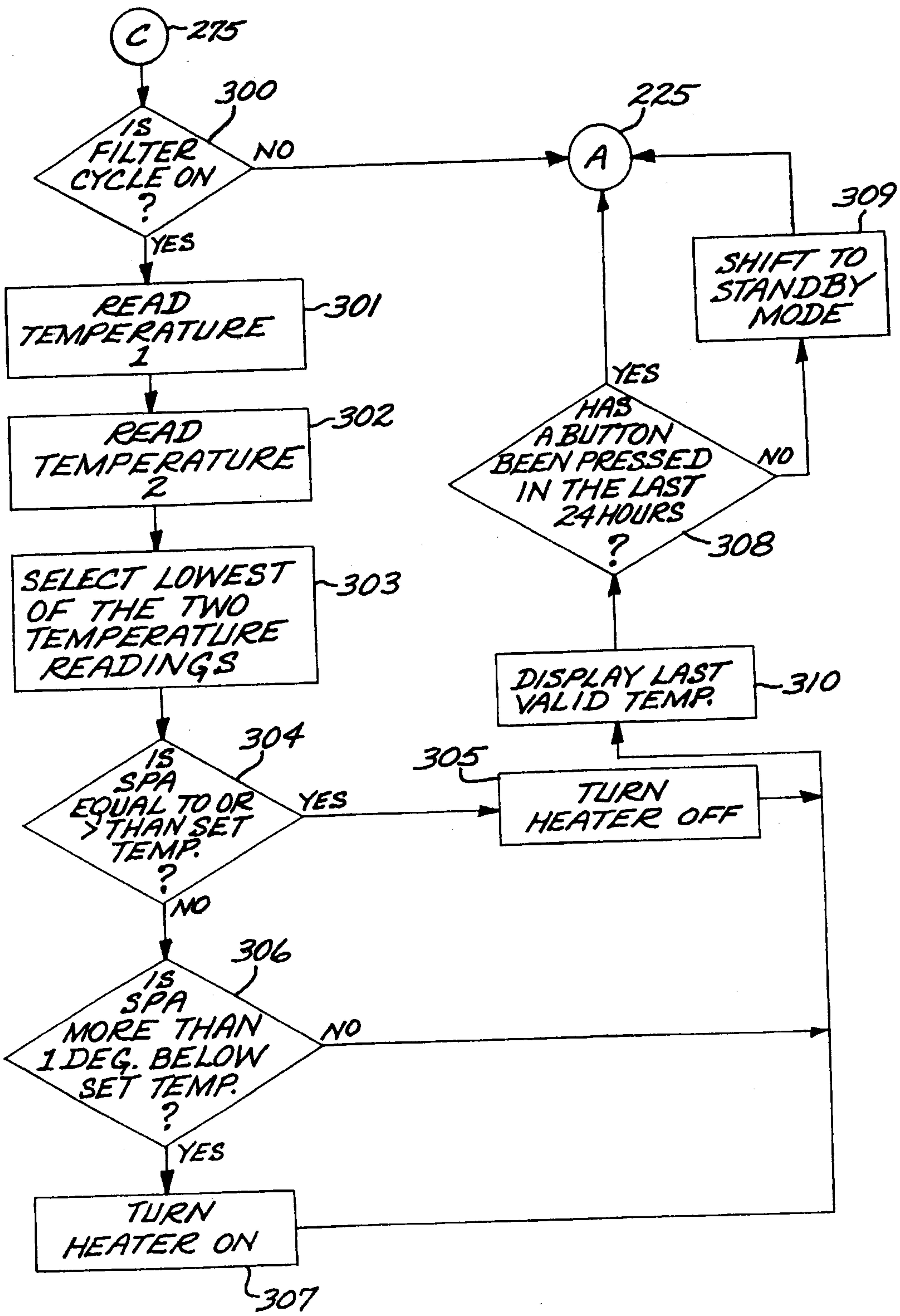

C
275
300
IS FILTER CYCLE ON ?
NO
YES
225
A
READ TEMPERATURE 1
301
READ TEMPERATURE 2
302
SELECT LOWEST OF THE TWO TEMPERATURE READINGS
303
IS SPA EQUAL TO OR > THAN SET TEMP. ?
304
YES
NO
305
TURN HEATER OFF
DISPLAY LAST VALID TEMP.
310
HAS A BUTTON BEEN PRESSED IN THE LAST 24 HOURS ?
308
YES
NO
SHIFT TO STANDBY MODE
309
IS SPA MORE THAN 1 DEG. BELOW SET TEMP. ?
306
NO
YES
TURN HEATER ON
307

FIG. 14

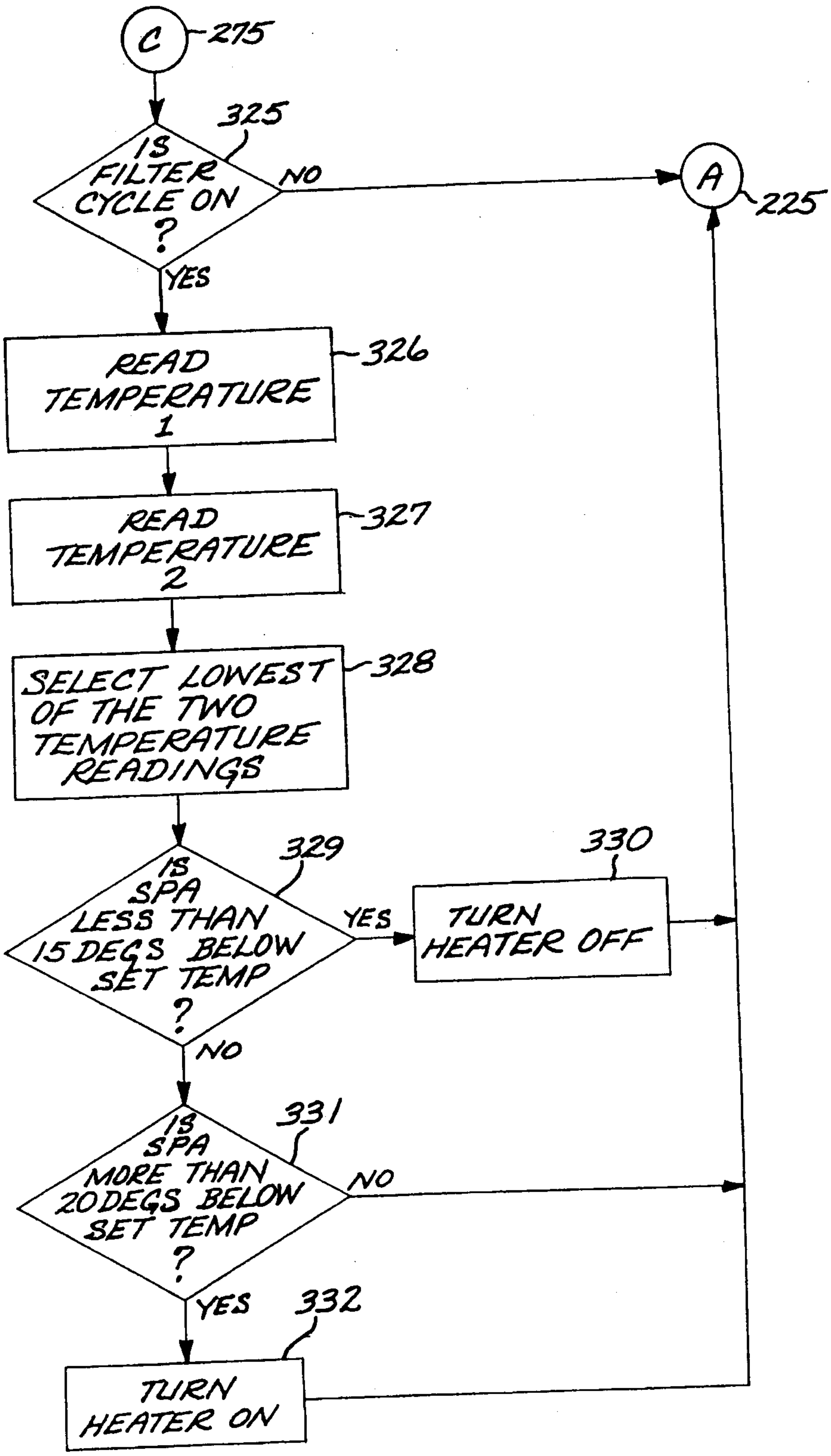
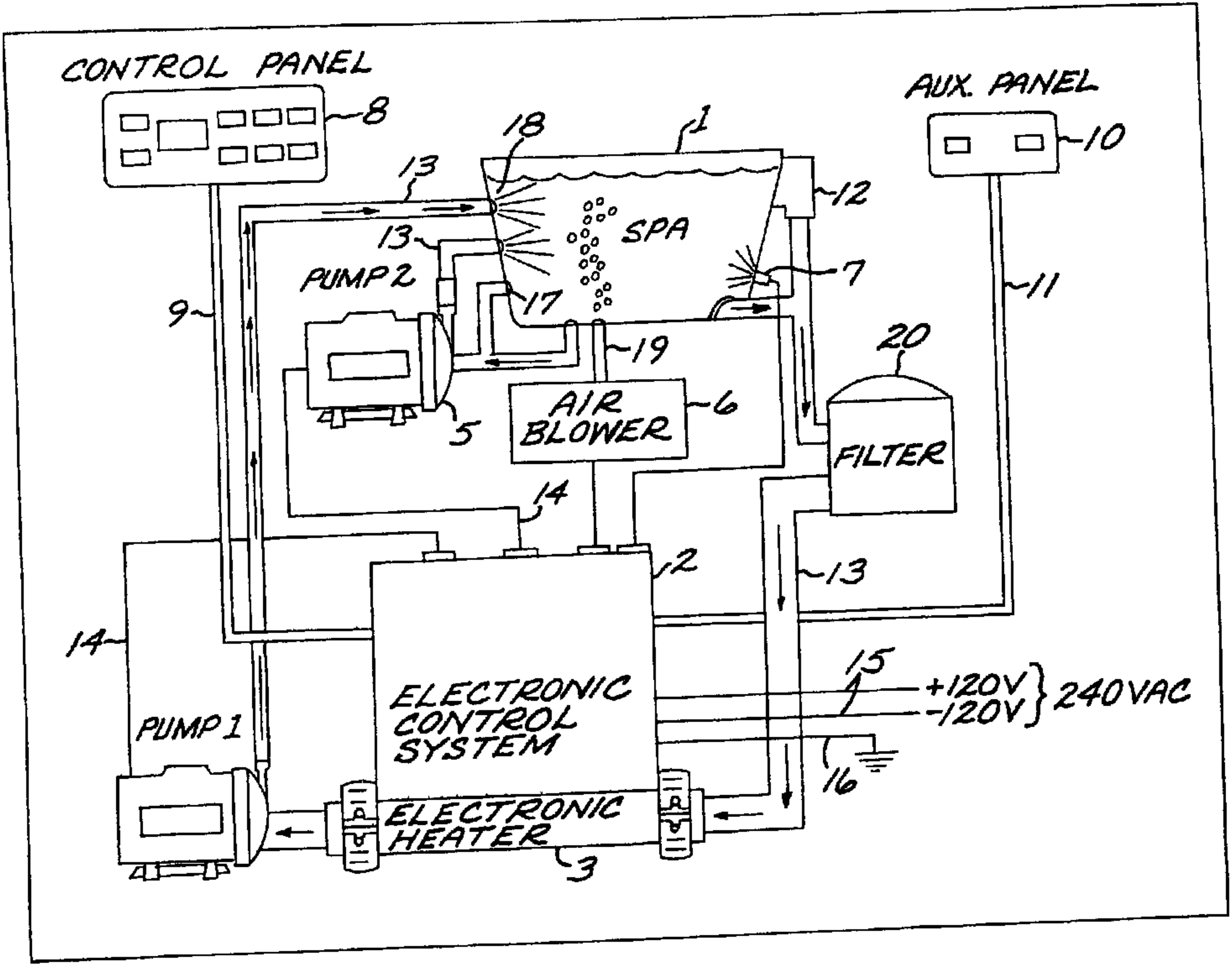

C
275
IS FILTER CYCLE ON ?
325
NO
A
225
YES
READ TEMPERATURE 1
326
READ TEMPERATURE 2
327
SELECT LOWEST OF THE TWO TEMPERATURE READINGS
328
IS SPA LESS THAN 15 DEGS BELOW SET TEMP ?
329
YES
TURN HEATER OFF
330
NO
IS SPA MORE THAN 20 DEGS BELOW SET TEMP ?
331
NO
YES
TURN HEATER ON
332

FIG. 15



CONTROL PANEL
8
AUX. PANEL
10
1
18
13
12
SPA
13
PUMP 2
7
17
9
11
19
20
AIR BLOWER
6
5
FILTER
14
2
13
14
15
ELECTRONIC CONTROL SYSTEM
+120V
-120V
240VAC
PUMP 1
16
ELECTRONIC HEATER
3