

- [54] **ELECTRONIC PROGRAMMER UNIT
FOR BURNER CONTROL**
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431/45
- [51] Int. Cl.**F23n**
- [58] Field of Search.....431/24, 25, 26

- [56]
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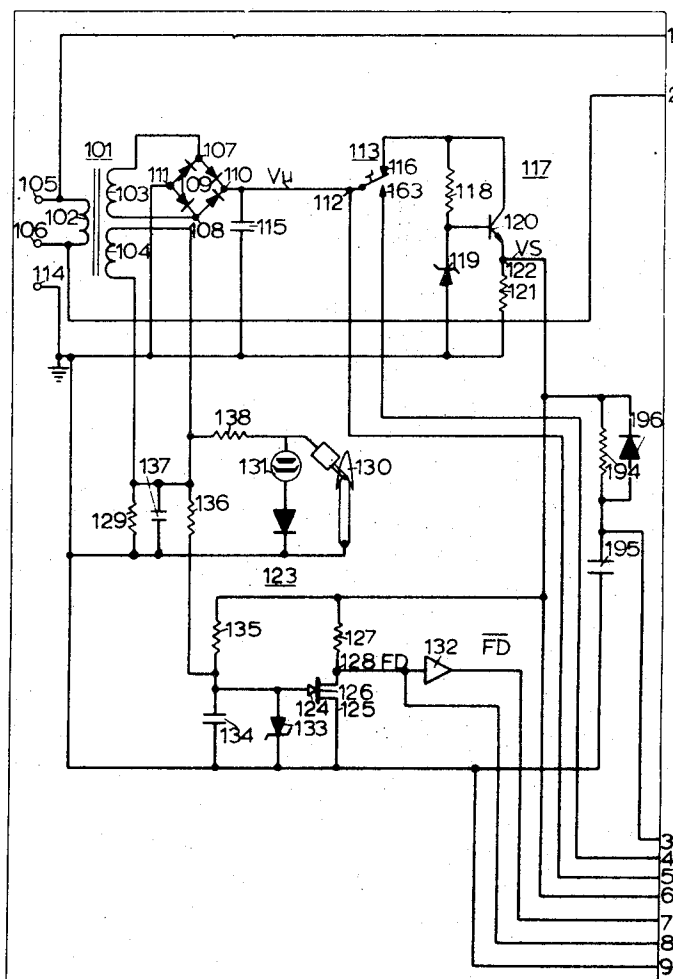
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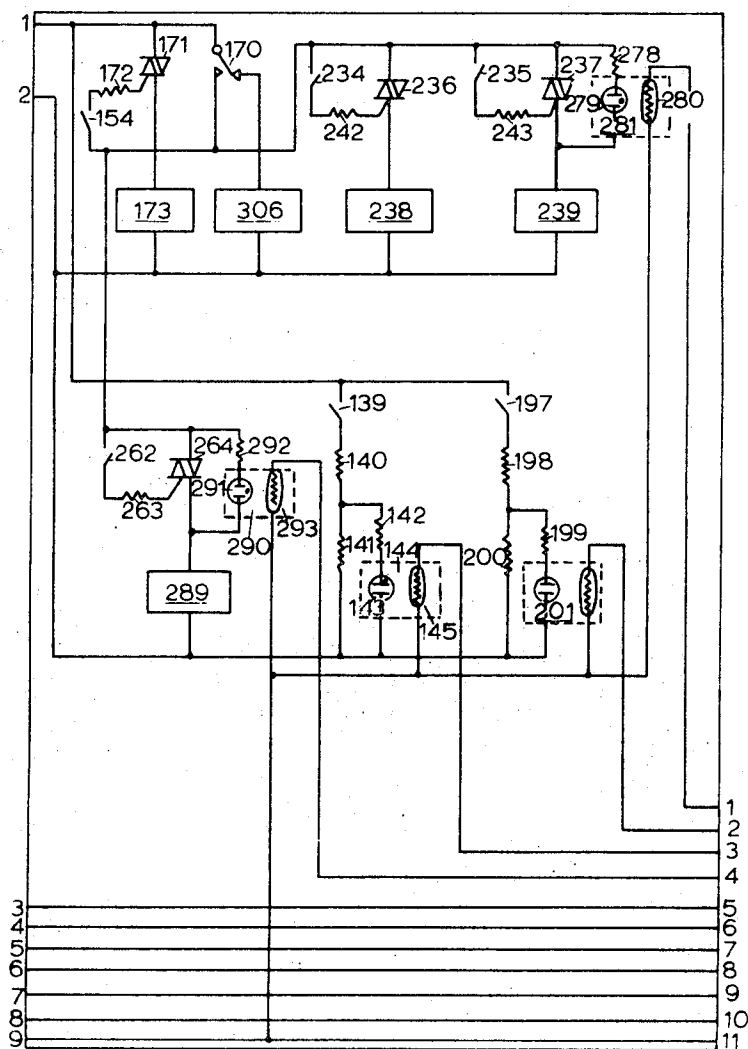
Primary Examiner—Carroll B. Dority, Jr.
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[57] **ABSTRACT**

An electronic programme timer means of solid state construction, for a fuel burner, said programme timer means comprising a control switch for initiating operation, a plurality of sequencing relays, flame sensing means connected to voltage comparators, voltage ramp generator, voltage follower and level detectors with output connected to said comparators for controlling said sequencing relays, feedback means to said comparators to ensure correct switching, temperature sensing means for switching said timer means and pressure sensing means for checking operation of blower purging means.

9 Claims, 6 Drawing Figures





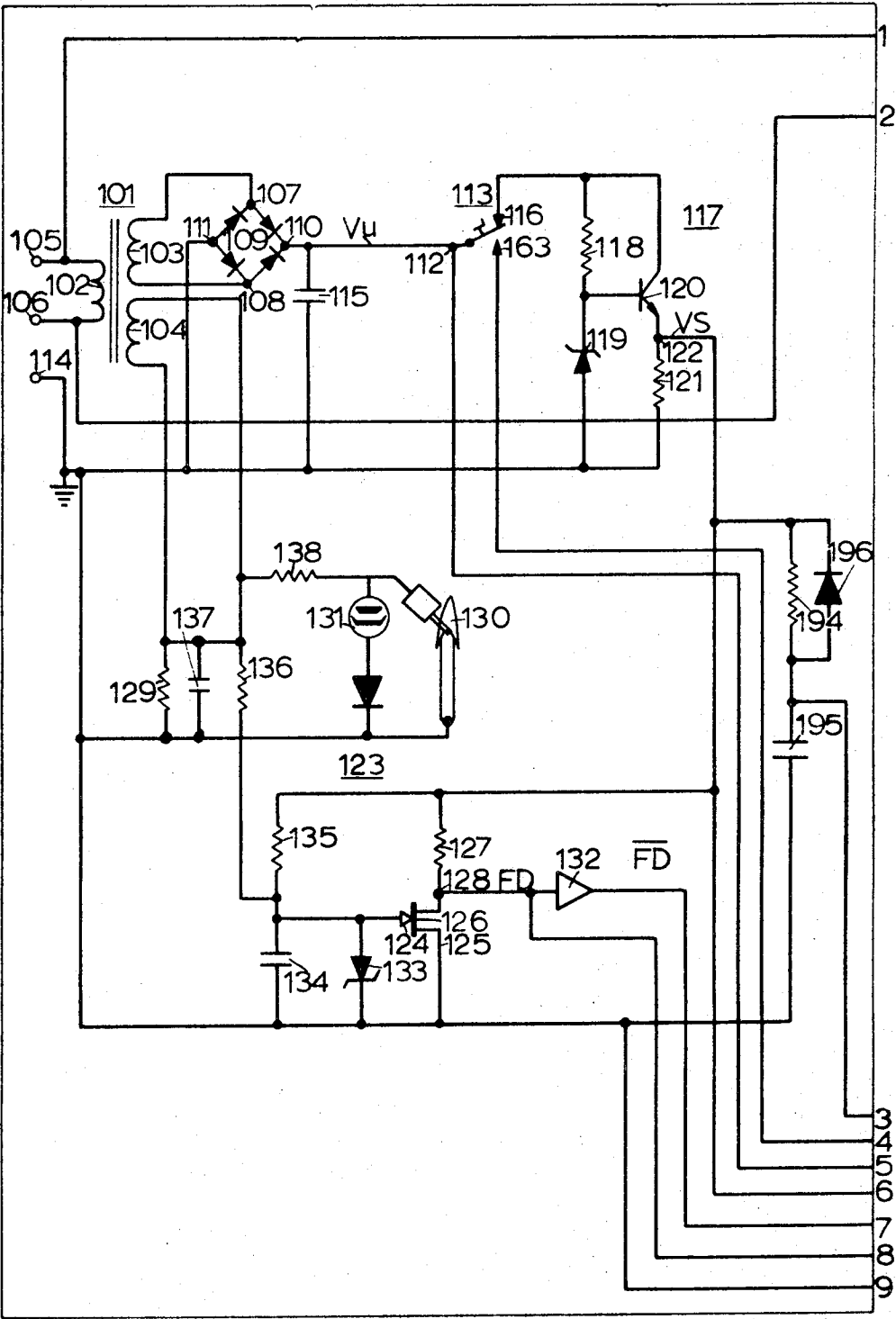


FIG. 1.

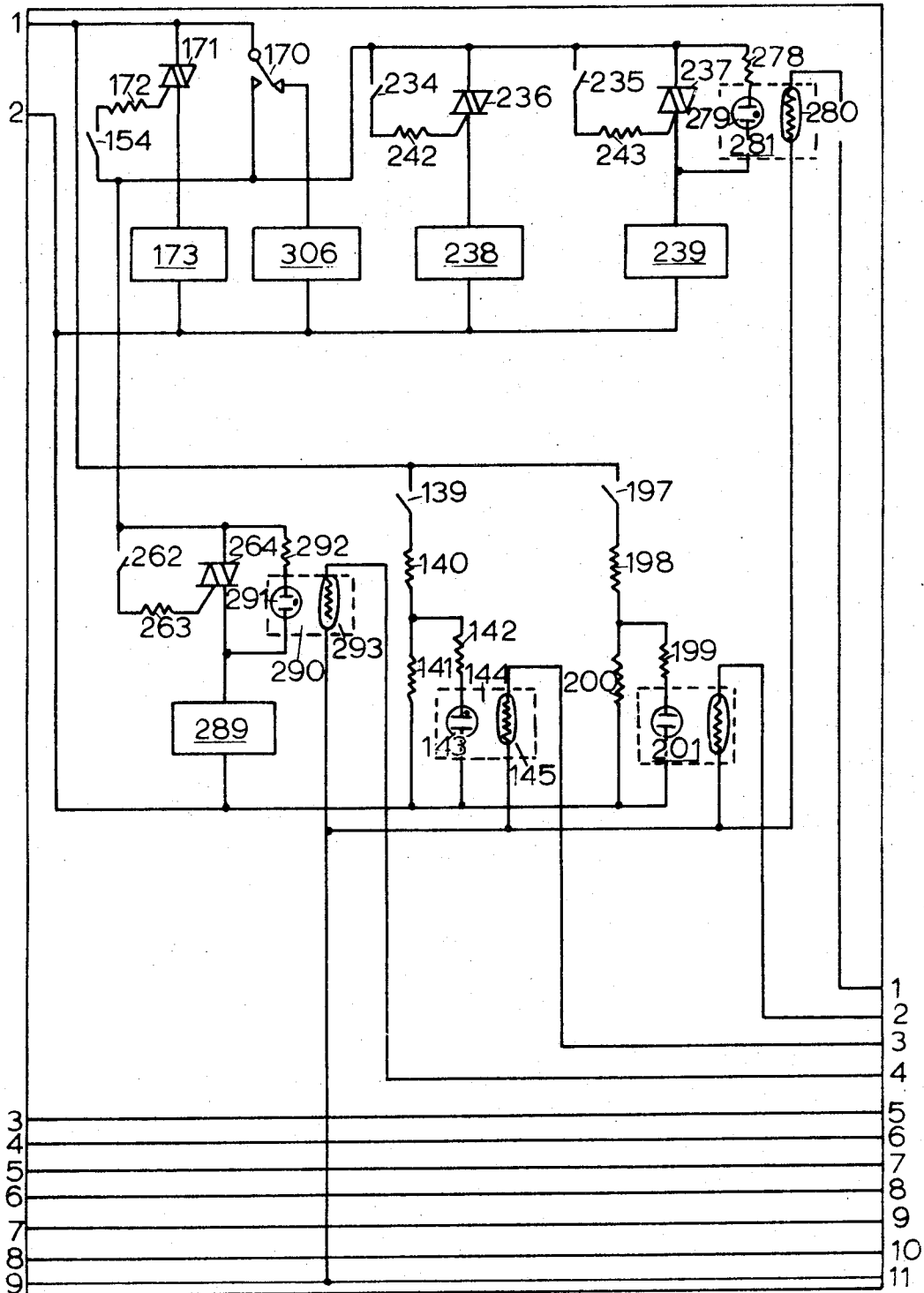


FIG. 2.

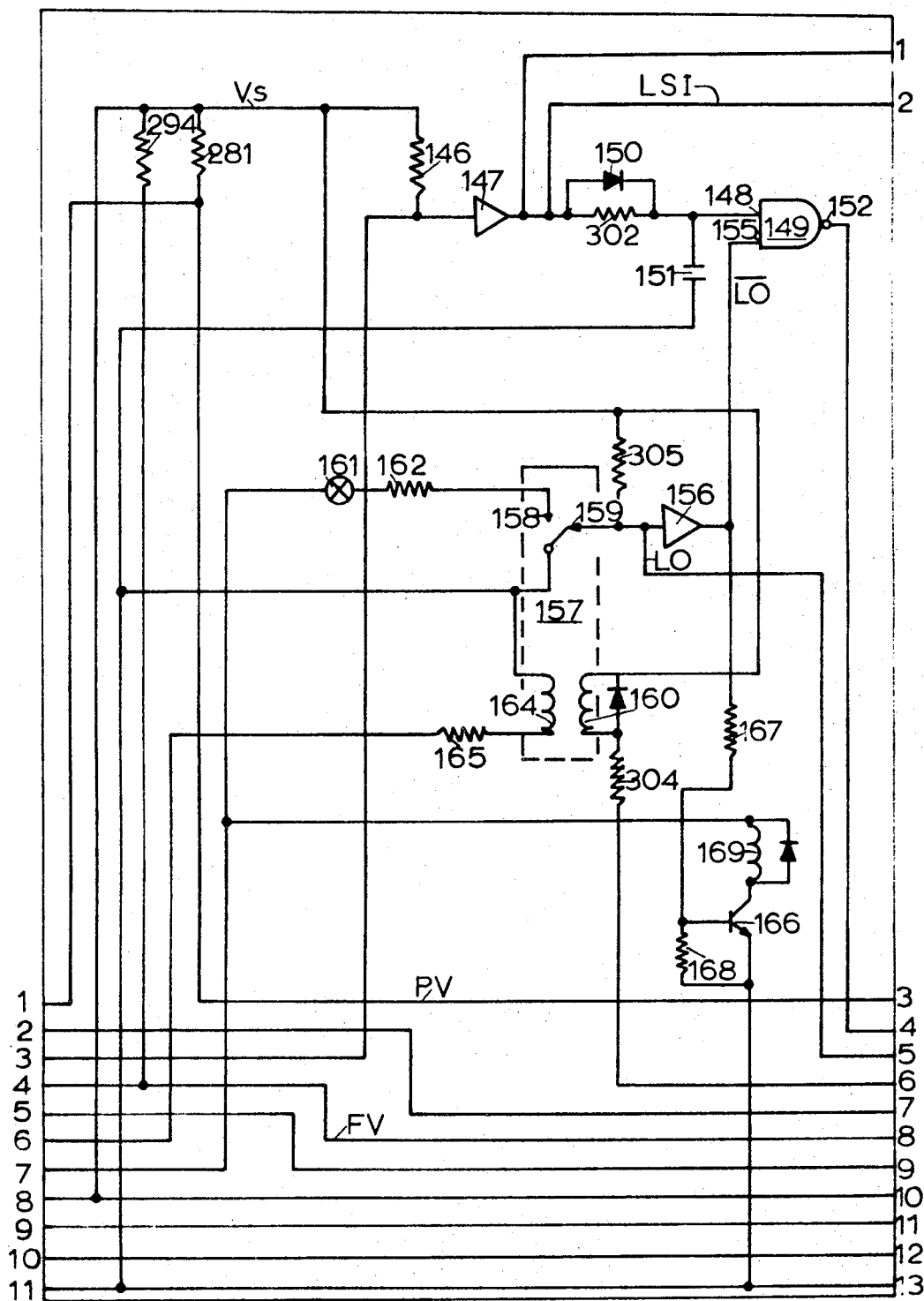


FIG. 3.

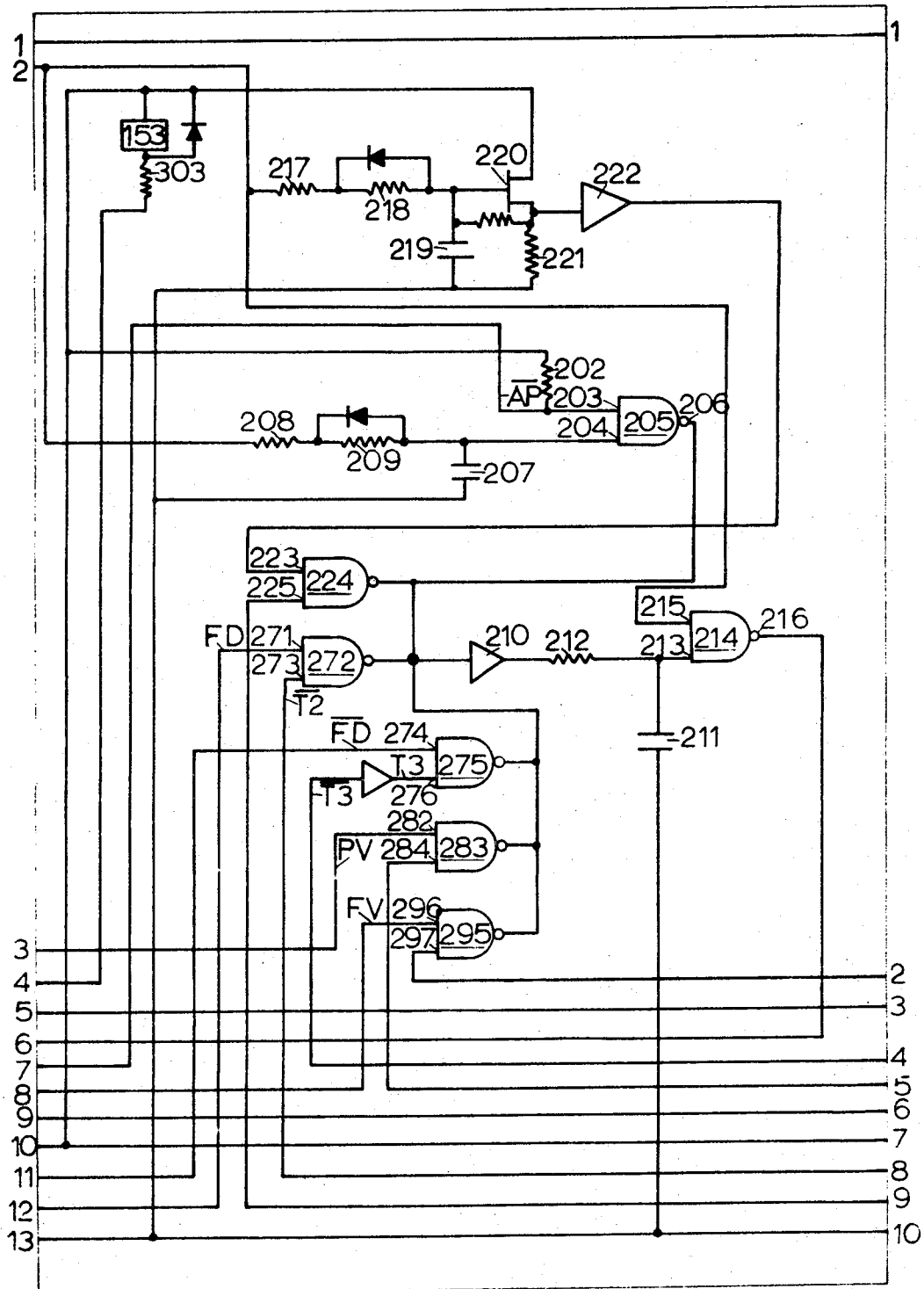


FIG. 4.

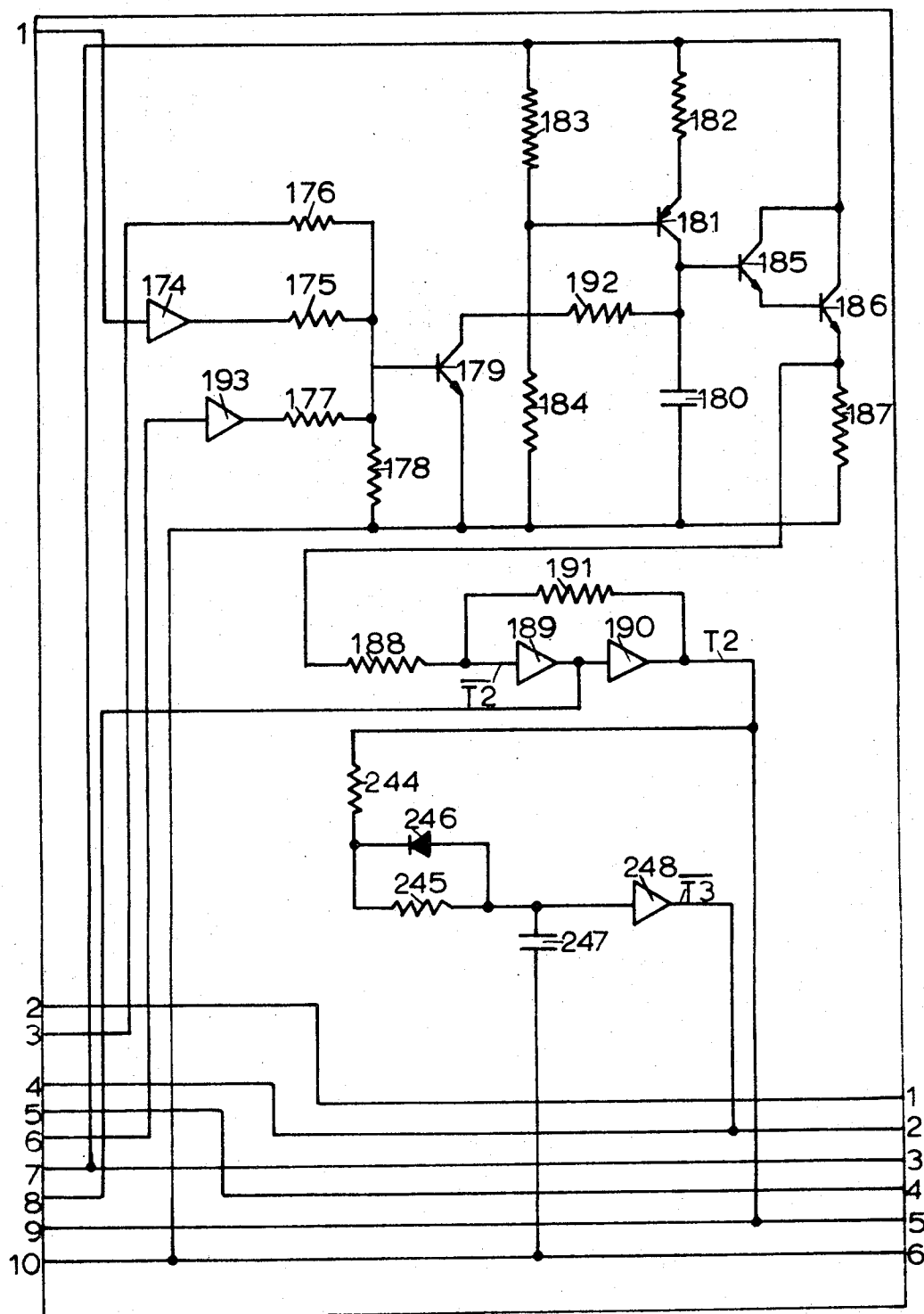


FIG. 5.

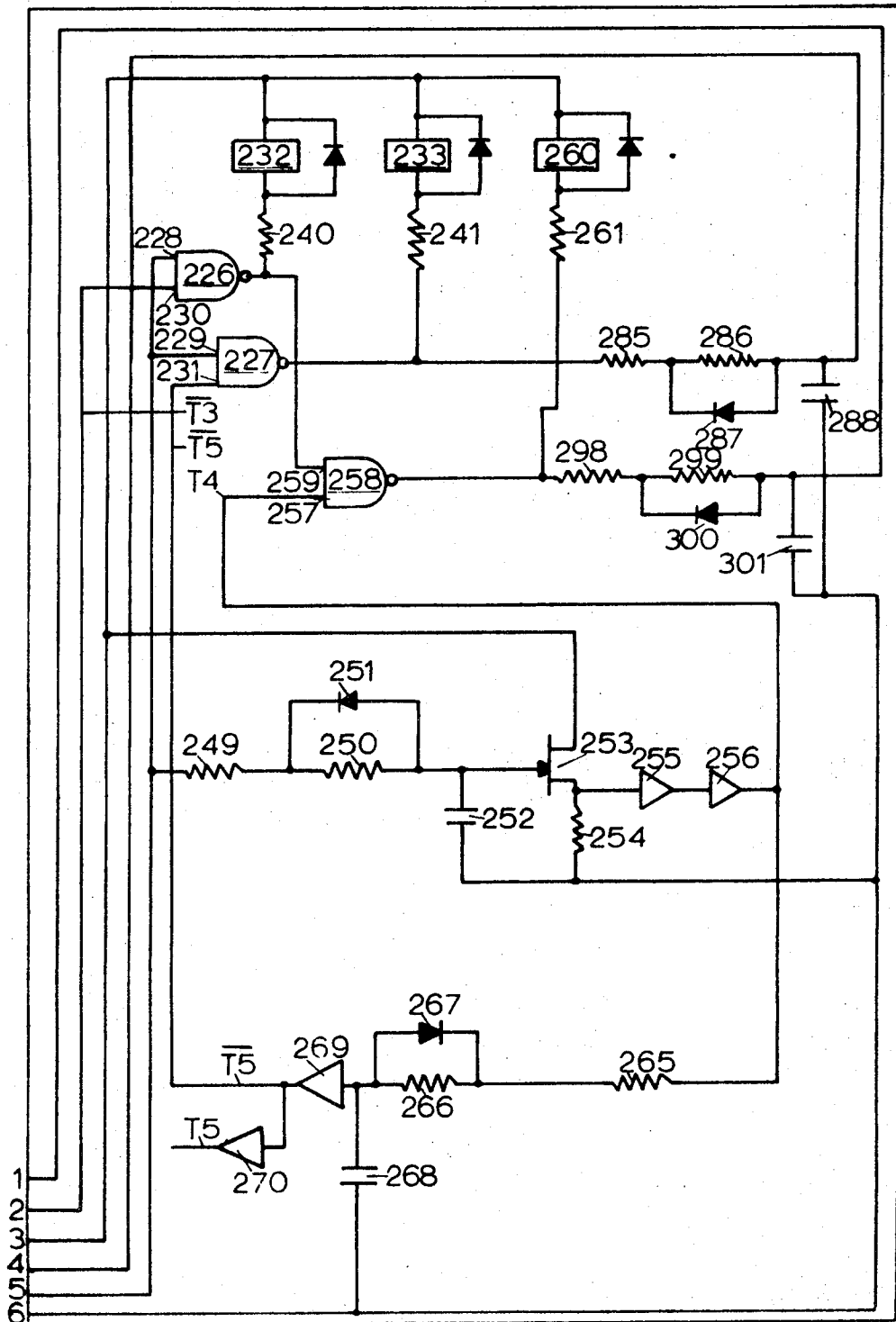


FIG. 6.

ELECTRONIC PROGRAMMER UNIT FOR BURNER CONTROL

This invention relates to electronic programme timer means and more particularly, although not exclusively, to programme timers for use with gas-fired heating installations.

Known installations using mechanically operated controls have necessitated frequent servicing, resulting in high cost maintenance, and in general such components have a comparatively short trouble-free life.

It is an object of the invention to provide an electronic programme timer means without mechanically actuated moving parts, being of solid state construction having simple circuitry and providing a long life without need of attention.

It is a further object of the invention to provide electronic safety circuits in conjunction with comparators which will self-test the various circuits of the timer and will shut down the complete system should any individual section malfunction.

According to the invention I provide an electronic programme timer means comprising a linear voltage ramp generator, a matching impedance voltage follower circuit and voltage comparators, wherein the follower circuit maintains substantially uniform linearity with the voltage gradient produced by the generator, the voltage comparators being sequentially actuated by an output signal of the follower circuit.

In another aspect of the invention I provide an electronic programme timer means for a fuel burner having electrically actuated ignition means, fuel valve means, pilot valve means, burner motor means and alarm means, said programme timer comprising:

- a. An operating control switch for initiating operation of the timer upon requirement,
- b. an electronic timer of solid state construction and a plurality of sequencing relays controlled thereby,
- c. flame sensing means with output connected to voltage comparators indicative of flame presence and flame absence,
- d. timer means comprising a voltage ramp generator, voltage follower and voltage level detectors with outputs fed to voltage comparators for operation of sequencing relays for switching circuits in sequence,
- e. feedback to said voltage comparators from said switched circuits to ensure that said switching circuits will only switch provided the fuel burner system is operating correctly and will reset said timer means on completion of an operating cycle, or, should malfunctioning occur, shut down the fuel burner system and reset said timer means,
- f. temperature sensing means for switching said timer means when pre-set temperatures are attained after initiation of said timer means by said operating control means,
- g. pressure sensing means for checking operation of blower means to ensure correct purging operations.

In order that the invention shall be readily understood I now describe a preferred embodiment for a gas-fired heating system, which is by way of example only, with reference to the accompanying drawings in which:

FIG. 1 shows the power supplies, voltage regulator, flame monitor and voltage ramp reset circuit,

FIG. 2 shows the safety cutout circuits,

FIG. 3 shows the retentive memory, lockout and warning circuits, and

FIG. 4, 5 and 6 show the voltage ramp generator, voltage follower, comparator and gating circuits for a program timer of a gas-fired heating installation.

INTRODUCTION

The function of the fuel burner control equipment is to automatically ignite the burner at the beginning of a heating period, monitor its correct operation, and shut down the burner at the end of the heating period, or as the result of abnormal operation.

On a typical burner the heating period is initiated by the decrease in temperature, of an enclosure to be heated, closing of contacts in a thermostat or similar control which switches on the burner motor, thereby providing a forced draught through the burner combustion chamber. This forced draught initially purges the chamber of old gas and the period of operation is known as the pre-purge period. After this period, a pilot flame is ignited by energizing a spark transformer to produce an ignition spark across spark electrodes and to open the pilot valve. After a period during which the pilot flame is established, the ignition spark is turned off and the main fuel valve is opened. After a further period, during which the main flame is established, the pilot flame is extinguished, leaving the burner in the normal running condition.

When the air, within the enclosure to be heated, reaches a predetermined temperature, the contacts of the thermostat open, thereby shutting down the burner.

Due to explosion hazards, a flame monitor is provided to shut down the burner in case of failure of the pilot or main flame, or both, in order to prevent an accumulation of unburnt fuel in the combustion chamber. In order to distinguish this type of shut-down from a normal shut-down, a lock-out device and warning signal are provided. The lock-out device prohibits the normal starting operation until a reset switch or push-button, in the vicinity of the burner, is operated.

CIRCUIT DESCRIPTION

The circuit is described with reference to FIGS. 1, 2, 3, 4, 5 and 6. The reference numerals 1 - 13 show interconnections between the parts of the circuit diagram shown in FIGS. 1 - 6.

OPERATION OF FLAME MONITOR

Transformer 101 (FIG. 1) has a primary winding 102 and two secondary windings 103 and 104, one terminal of the primary winding being connected to 105 which is the line side of an AC power supply, while the other terminal is connected to 106, which is the neutral side of the power supply. Secondary winding 103 is connected across input terminals 107 and 108 of a rectifier bridge 109 which changes the alternating voltage to a rectified voltage with positive at terminal 110 and negative at 111. The output terminal 110 of the bridge is connected to the terminal 112 of a lock-out reset push-button 113, and the negative return 111 is connected to the earth side 114 of the AC power supply. Capacitor 115 is connected across the output of the rectifier bridge 109 to reduce the AC ripple on the output at 110.

The unregulated output at 110 and called V_u , is connected through the normally closed contacts 112 and 116 of the lock-out reset push-button 113 to a voltage regulator circuit 117. The voltage regulator circuit 117 consists of resistor 118 and zener diode 119 connected between terminal 116 and earth 114, the voltage developed across 119 providing the reference voltage for the regulator. Transistor 120 and resistor 121 form the output stage of the regulator generating a regulated power supply from point 122 for use in various semiconductor circuits throughout the equipment. This regulated voltage will be called V_s .

Secondary winding 104 of transformer 101 provides an AC voltage for energizing a flame monitor circuit 123. When no flame is present there is only a small potential difference between the gate 124 and drain 125 of the field effect transistor 126. Thus 126 conducts, causing a drop in potential across resistor 127, which is connected between V_s and the source 128 of 126, so the source 128 of 126 is, therefore, maintained at approximately earth potential.

When a flame is present, since a flame has the property of conducting an electrical current readily to ground, a difference of potential is developed across resistor 129, which makes 124 of 126 negative with respect to 125. This effect is also produced when light from a flame 130 impinges on a photocell 131. Thus 126 does not conduct and only a small potential is developed across 127, so the source 128 of 126 is, therefore, maintained at approximately V_s .

The potential at the source 128 of 126 can, therefore, assume two values, approximately V_s and approximately earth, representing flame present and flame absent respectively. Throughout the logic circuitry, a binary "1" is represented by approximately V_s and a binary "0" by approximately earth. Thus the binary signal, flame detected, existing at 128 FD, is a "1" when the flame is present and a "0" when the flame is absent. The signal FD is applied to a logic inverter 132 whose output is, therefore, "0" when the flame is present, and "1" when the flame is absent. This is the inverse of signal FD and is denoted $\overline{FD}$.

Zener diode 133, capacitors 134 and 137, and resistors 135, 136 and 138, are components for the basic settings of the flame monitoring circuit 123.

OPERATION OF BURNER CONTROL EQUIPMENT - STARTING

The line side 105 of the AC voltage supply is connected to one terminal of a thermostat 139 (FIG. 2), and when the thermostat closes, the AC voltage supply is applied across a potential divider comprising resistors 140 and 141. The resulting potential across resistor 141 is applied to a neon indicator 143 through a resistor 142. Neon indicator 143 forms part of a neon-photo-resistor unit 144. When the neon 143 illuminates the photo-resistor 145, the resistance value of 145 is reduced to a low value. When the neon 143 is extinguished and the photo-resistor 145 is not illuminated, the resistance is increased to a high value. Hence the resistive value of photo-resistor 145 monitors the position of the thermostat. This system isolates the AC voltage supply from the logic circuitry and allows low voltages to be used throughout the latter with a corresponding increase in life and reliability. The photo-

resistor 145 of 144 forms a potential divider between earth and V_s with resistor 146 (FIG. 3). When 139 is open and 143 extinguished, 145 has a high resistive value and only a small potential difference is developed across 146, i.e. the output of the potential divider is approximately earth ("0"). Thus the input to logic inverter 147 (FIG. 3) is a "1" when 139 is open and a "0" when 139 is closed. The output of 147 is denoted LS1 and is a "0" when 139 is open and a "1" when 139 is closed.

The output of 147 is applied to one input terminal 148 of NAND gate 149 via diode 150. When 139 closes, the output of 147 rises from approximately earth potential to approximately V_s and capacitor 151 is quickly charged to approximately V_s via 150. Thus, practically, as soon as 139 closes, a logic "1" is applied to 148 of 149 which was previously at logic "0" with the output terminal 152 at logic "1", i.e. approximately V_s . In this condition there is no potential across relay 153 (FIG. 4) and contacts 154 (FIG. 2) would be open. When the input at 148 of 149 goes to logic "1", the output of 149 is then dependent on the logic value of $\overline{LO}$, a signal applied to the second input 155 of 149.

Logic signal $\overline{LO}$ is derived from the output of an inverter 156 (FIG. 3) which monitors the position of retentive memory contacts 157 (FIG. 3). 157 may be in one of two states, set 158 or reset 159. Under normal conditions 157 will be at 159 and the voltage drop across 305 gives a logic "0" which will be applied to the input of 156 making $\overline{LO}$ equal "1". Under abnormal conditions a logic "0" (approximately earth) is applied to the set coil 160 of 157 via resistor 304, and this changes 157 to the set condition, breaking contact 159 and making contact 158, thus removing the logic "0" from 156 and applying logic "1", i.e. L.O. becomes "1" and $\overline{LO}$ becomes "0". At the same time a lock-out alarm lamp 161 is illuminated via a resistor 162. 157 can then only be reset by operating a lock-out reset push-button 113 (FIG. 1), which applies potential V_u across a reset coil 164 via contact 163 (FIG. 1) and a resistor 165 (FIG. 3).

Assuming that conditions are normal and that $\overline{LO}$ is equal to "1", the closing of 139 immediately applies a logic "1" to 148 of 149, resulting in the output of 149 changing from logic "1" to logic "0". This results in the application of potential V_s across 153 (FIG. 4), causing contacts 154 (FIG. 2) to close. Logic signal $\overline{LO}$ is also applied to the base of a transistor 166 via biasing network resistors 167 and 168 (FIG. 3). Under normal conditions $\overline{LO}$ is approximately V_s and this results in a current flow through the base emitter junction of 166. The transistor, therefore, conducts current from collector to emitter, causing potential V_u to be applied across the coil 169. Thus under normal conditions 169 is energized and contacts 170 (FIG. 2) are in the energized state. The line side of the AC voltage at 105 (FIG. 1) is, therefore, applied to one side of contact 154 (FIG. 2) via the energized side of contacts 170. Hence, when 139 closes, contact 154 closes and applies the line side of the AC voltage from 105 to the gate of a bi-directional thyristor 171 via a resistor 172. This provides a low conductance path for AC current across the main electrodes of 171, resulting in energization of a burner motor 173. If abnormal conditions occur 166 does not conduct, 169 becomes de-energized, and a warning 306 operates via contacts 170.

The logic signal LS1 is also applied to inverter 174 (FIG. 5) to produce signal $\overline{LS1}$ which is applied to one terminal of a resistor 175, the other terminal being commoned with terminals of two other resistors 176 and 177. The potential developed across resistor 178, connected between the common terminals of resistors 175, 176 and 177, and earth, depends on the potential applied to the other terminals of 175, 176 and 177. If these potentials are all approximately earth, then only a small potential is developed across 178, i.e., across the base emitter junction of a transistor 179. 179 does not, therefore conduct from collector to emitter, and permits a capacitor 180 to charge up through the emitter collector circuit of a transistor 181. The rate of charge of 180 is a constant determined by the value of a resistor 182 and the capacitor 180. The aiming potential of the voltage ramp generated across 180 is determined by a potential divider network 183, 184, connected to the base of 181. The voltage ramp generated across 180 is applied to a voltage follower circuit formed by transistors 185, 186, and output resistor 187. The voltage follower offers a very high input impedance to the voltage ramp generator output, and at the same time offers a very low output impedance to a level detector or voltage comparator circuit formed by an input resistor 188, logic inverters 189 and 190, and a feedback resistor 191. The voltage across 187 rises linearly and in step with the voltage across 180. Initially the output T2 of 190 is held at logic "0" and the voltage at the input to 189 rises linearly in a scaled-down version of the voltage across 187. When the voltage at the input to 189 reaches the switching potential of 189, its output T2 switches to logic "0", and the output T2 of 190 switches to logic "1". Due to 191 this switching is regenerative and T2 reaches logic "1" very quickly. The voltage ramp level at which the level detector switches is determined by the potential divider 191 and 188. The time interval between the start of the voltage ramp and the switching of T2 from logic "0" to logic "1" forms the pre-purge period of the burner.

Before 139 closes and LS1 is set to logic "1", the output of 174, $\overline{LS1}$ is logic "1". Hence the input terminal of 175 is approximately Vs and there is a large enough potential across 178 to allow the base emitter diode of 179 to conduct, and the collector-emitter circuit of 179 to conduct, resulting in 180 discharging through a resistor 192 and the collector-emitter circuit of 179. This effectively prevents generation of the voltage ramp.

When 139 closes and LS1 is set to logic "1", $\overline{LS1}$ becomes logic "0", causing 179 to become non-conducting and permits the voltage ramp to be generated. Hence the pre-purge period starts when LS1 is set to logic "1", provided that the input ends of 176 and 177 are also at approximately earth potential. Under normal conditions LO equals logic "0", and the input end of 176 is at approximately earth potential. Should a lock-out condition occur LO equals logic "1", the input end of 176 becomes approximately Vs, 179 conducts and the voltage ramp is reset to zero voltage. Also under normal conditions the potential at the input end of 177 is at approximately earth potential, as this is connected to the output terminal of a logic inverter 193, whose input potential is normally Vs.

A voltage ramp reset circuit (FIG. 1) formed by a resistor 194, a capacitor 195 and a diode 196, delays the

build-up of Vs at the input to 193. When AC power is initially applied to the unit, Vs is established quickly from the output of 117. However, the potential at the input to 193 will be established slowly, since 195 has to charge up through 194, and until the potential across 195 reaches the switching potential of 193 the output of the latter will be approximately Vs. The input potential of 177 will, therefore, be approximately Vs and the voltage ramp generator will be reset. After a short time the potential across 195 reaches the switching potential of 193 and the output of 193 switches to approximately earth, removing the initial reset condition from the voltage ramp generator.

Under normal operating conditions, therefore, the switching of LS1 from logic "0" to logic "1" initiates the voltage ramp. The pre-purge period is timed to last for from 35 to 40 seconds.

OPERATION OF AIR PRESSURE CHECKING SYSTEM

One feature of the fuel burner control equipment is the checking of the air pressure in the combustion chamber to establish that the burner motor is in fact producing a forced draught. Under normal conditions an air pressure switch 197 (FIG. 2) in the combustion chamber will operate a short time after the burner motor has been switched on. This switch is connected in a resistor divider network comprising 198, 199, 200, and neon-photo-resistor network 201, similar to that of 139. This operates in the same manner as the system for the thermostat 139, so that when the air pressure switch 197 is open, only a small potential exists across resistor 202 (FIG. 4), and when 197 is closed, a large potential exists across 202. Thus, when 197 is open, logic signal $\overline{AP}$, no air pressure, is "1", and when 197 is closed, $\overline{AP}$ is equal to "0".

Signal $\overline{AP}$ is applied to one of the inputs 203 of NAND gate 205. The other input 204 is connected to one terminal of a capacitor 207. When LS1 is equal to logic "0" the voltage at this terminal is approximately earth, and hence the output of 205 at 206 is at logic "1" irrespective of the signal on the input of 205 at 203. When 139 (FIG. 2) closes and LS1 is changed to logic "1", 207 (FIG. 4) starts to charge up to potential Vs through resistors 208 and 209. The potential on input 204 or 205 will, therefore, increase slowly to the switching potential of 205, the time taken being primarily dependent on the CR time constant provided by 207 and 209. This time constant is chosen so that 197-(FIG. 2) will close, i.e. $\overline{AP}$ equals logic "0", before the input at 204 of 205 (FIG. 4) reaches switching potential when the equipment is operating correctly. This means that under normal operating conditions the output at 206 of 205 will always be logic "1". A time constant is chosen which permits about 5 seconds for 197 (FIG. 2) to close.

If an abnormal condition occurs and 197 does not close after 173 has been operated for 5 seconds, the output 206 of 205 (FIG. 4) switches to logic "0", since both inputs 203 and 204 will become equal to logic "1". This pulls the input of inverter 210 to logic "0" and hence its output to logic "1". This in turn causes a capacitor 211 to start to charge to approximately Vs through a resistor 212, thus producing a short delay before the abnormal condition is signalled

to input 213 of NAND gate 214. Since input 215 of 214 is also at logic "1", due to LS1 equalling logic "1", the output of 214 at 216 will be switched to logic "0". This results in potential Vs being applied across 160 of 157 (FIG. 3). In the "set" condition the equipment goes to the lock-out state, as previously explained. Hence, failure of 197 to operate within a given time after operation of 173 results in a lock-out.

OPERATION OF VOLTAGE RAMP GENERATOR CHECKING SYSTEM

A further feature of the fuel burner control equipment is the checking of the voltage ramp generator timing system. Under normal conditions the output T2 of the lever detector (FIG. 5) will change from logic "0" to logic "1" a certain time after LS1 has changed from logic "0" to logic "1". Signal LS1 is fed through resistors 217 and 218 (FIG. 4) to one terminal of a capacitor 219 which commences charging at a rate determined by the CR time constant formed by 217, 218 and 219. A field effect transistor 220 forms a voltage follower with a high input impedance so that there is negligible load current drawn from 219. The voltage across a resistor 221 follows that across 219 and is applied to a logic inverter 222. Thus, until the voltage across 221 has risen to the switching potential of 222 the output of the latter remains at logic "1". The time constant is chosen so that the time taken for 222 to be switched is slightly shorter than the time taken for T2 to be switched to logic "1". The output of 222 is applied to one input 223 of a NAND gate 224, and T2 is applied to the second input at 225, giving a normal output from 224 of logic "1". If the voltage ramp generator is faulty and rising too quickly, the pre-purge period will be too short, and it is desirable, therefore, to cause a lock-out. In this case T2 switches too soon and 225 of 224 will go to logic "1" before the input at 223 has switched to logic "0". The result of both inputs being at logic "1" is to switch the output of 224 to logic "0". This pulls the input to 210 to logic "0", resulting in a lock-out condition, as previously described. Under correct voltage, ramp generation input 223 of 224 will switch to logic "0" before input 225, thus maintaining a logic "1" at the input to 210.

OPERATION OF PILOT IGNITION

At the end of the pre-purge period T2 changes from logic "0" to logic "1". T2 is applied to NAND gates 226 and 227 (FIG. 6) at inputs 228 and 229 respectively. Until time signals T3 and T5 are changed from logic "0" to logic "1", the other inputs, at 230 and 231 respectively, will be at logic "1". Hence, when T2 changes to logic "1", the outputs of 226 and 227 change to logic "0", and relay coils 232 and 233 are energized via resistors 240 and 241. Relay contacts 234 and 235 (FIG. 2) switch on, via resistors 242 and 243, bi-directional thyristors 236 and 237, which apply power to the ignition transformer 238 and a pilot valve 239. The ignition spark stays on until signal T3 goes to logic "1". (T3 goes to logic "0" and returns the output of 226 to logic "1"). T3 is generated by a network comprising resistors 244, 245, diode 246, capacitor 247 and inverter 248 (FIG. 5). When T2 goes to logic "1", 247 charges up through 244 and 245, until its voltage had reached the switching level. The time constant is

chosen so that this takes approximately 4 seconds. Hence the ignition spark is switched on for approximately 4 seconds, and under normal conditions the pilot flame should be burning.

IGNITION OF MAIN FLAME

At the end of the pre-purge period T2 changes to logic "1". T2 is applied to a timing network (FIG. 6) comprising resistors 249, 250, 254, diode 251, capacitor 252, transistor 253 and inverters 255, 256, and causes 252 to charge up at a rate determined by the circuit constants. 253 and 254 form a high input impedance voltage follower, and the potential across 254 follows that across 252. After a time interval, in this case approximately 14 seconds, the potential across 254 reaches the switching level of 255 and the output of 255 changes from logic "1" to logic "0". This signal is applied to inverter 256, whose output simultaneously goes from logic "0" to logic "1". The signal output of 256, T4, is applied to one of the inputs, 257 of NAND gate 258, the other input at 259 being connected to the output of 226, which is the gate controlling ignition. Under normal conditions the ignition should be off and the output of 226 should be at logic "1" when the input 257, T4, is switched to logic "1". Hence the output of 258 will normally go to logic "0" when T4 goes to logic "1", and a relay coil 260 is energized via a resistor 261. Energization of 260 makes contacts 262 (FIG. 2) which switches, via a resistor 263, a bi-directional thyristor 264 to "on," thereby applying power to a fuel valve 289. Application of the output of 226 to 259 of 258 ensures that main fuel cannot be switched on before the ignition spark has been removed.

At this stage the main fuel valve is open and the pilot flame is burning, and, under normal conditions, the main flame is ignited. The pilot flame remains on for a further 4 seconds before being cut off by timing signal T5 going to logic "1", T5 going to logic "0", and causing the output of 227 to go to logic "1", thereby switching off 233 (FIG. 6) and 237 (FIG. 2), removing power from 239.

The timing signal T5 is generated from T4 by its application to a timing network comprising resistors 265, 266, diode 267, capacitor 268 and inverters 269, 270 (FIG. 6). This circuit provides a delay of approximately 4 seconds between signal T4 going to logic "1" and signal T5 going to logic "1".

After T5 has gone to logic "1" only the burner motor and main fuel valve are left on, and the starting sequence is complete.

CHECKING ABSENCE OF FLAME DURING PRE-PURGE PERIOD

The absence of flame during the pre-purge period is checked by application of signal FD (FIG. 1) to input 271 of NAND gate 272 (FIG. 4) and the inverse of T2, i.e. signal $\overline{T2}$ (FIG. 5) to the input 273 of 272 (FIG. 4). Normally there will be no flame during the pre-purge period (T2), i.e. FD equals logic "0". Hence the output of 272 should normally be logic "1". If flame does appear during this period, signal FD equal to logic "1" together with signal $\overline{T2}$ equalling logic "1" will pull the output of 272, and hence the input to 210, to logic "0". As previously described, this results in a lock-out.

CHECKING PRESENCE OF FLAME AFTER IGNITION

The presence of flame after ignition is checked by application of signal $\overline{FD}$ (FIG. 1) to input 274 of NAND gate 275 (FIG. 4) and timing signal T3 to the other input at 276 via inverter 277 which inverts signal $\overline{T3}$. Normally there will be flame after ignition, period T3, i.e. FD equals logic "1" and $\overline{FD}$ equals logic "0". Hence the output of 275 should normally be logic "1". If the flame is extinguished during this period, $\overline{FD}$ equals logic "1", together with T3 equalling logic "1", will pull the output of 275, and hence the input of 210 to logic "0". As has previously been described, this results in a lock-out.

CHECKING PILOT VALVE CIRCUIT FAILURE

Correct working of the pilot valve circuit is checked by using a neon-photo-resistor combination, 281, comprising resistor 278, neon 279 and photo-resistor 280 (FIG. 2). When 237 is switched off, 239 is inoperative and 279 has full mains voltage applied across it. It is, therefore illuminated, and the resistive value of 280 is low. 280, together with resistor 281 (FIG. 3) forms a potential divider across Vs and earth, whose output PV is equal to logic "0" when 279 is illuminated, and equal to logic "1" when 279 is extinguished. The signal PV is applied to one input 282 of NAND gate 283 (FIG. 4). The other input at 284 is connected to the output of 226 (FIG. 6) through a timing network comprising resistors 285, 286, diode 287 and capacitor 288. This has the effect of delaying the change of the output of 227 from logic "0" to logic "1" without delaying its change from logic "1" to logic "0". If the output of 227 changes from logic "1" to logic "0", 288 discharges quickly through 287, 285 and the output circuit of 227, and hence the potential on 284 of 283 quickly falls to logic "0". If the output of 227 changes from logic "0" to logic "1", 288 charges slowly through 285 and 286, hence 283 (FIG. 4) input 284 does not reach switching potential so quickly.

Under normal conditions, prior to the pilot valve being opened, signal PV is equal to logic "0" and the output of 283 is equal to logic "1". If the pilot valve circuit goes "open circuit," the neon 279 will lose its main voltage supply, become extinguished, and signal PV will become equal to logic "1". Since, prior to operation of 239, the output of 227 is equal to logic "1" and the two inputs to 283 are both equal to logic "1", the output of 283 is equal to logic "0" and the input to 210 is also equal to logic "0" which, as previously described, results in a lock-out. Should the bi-directional thyristor 237 become "short circuited" during this period, 279 would again be extinguished and lock-out would occur.

When 239 is operated the output of 227 is to logic "0" and input 284 of 283 also immediately goes to logic "0". The output of 283, therefore, remains at logic "1" and the change of PV to logic "1" has no effect.

When 239 is de-energized the output of 227 goes to logic "1", but input 284 of 283 does not immediately change to logic "1", thus allowing time for 233, 235 and 237 to become inoperative. When the input 284 of 283 changes to logic "1", the pilot valve circuit is again monitored, as previously described.

CHECKING MAIN VALVE CIRCUIT FAILURE

Correct operation of the main valve circuit is checked by using a neon-photo-resistor combination 290 (FIG. 2) comprising neon 291, resistor 292 and photo-resistor 293. The circuitry used for checking main valve circuit failure is similar to that used for checking pilot valve circuit failure. Resistor 294 (FIG. 3) forms a potential divider across Vs and earth with 293, to give an output FV which operates in a manner identical to signal output PV. NAND gate 295 with signal output FV at 296 has a similar function to 283, and the transfer of the output of 258 to input 297 of 295 is delayed in a similar way through a network comprising resistors 298, 299, diode 300 and capacitor 301. As with the pilot valve, main valve circuit checking is performed prior to main gas valve operation.

BURNER SHUT-DOWN

The burner is shut-down when contacts 139, thermostat, open, causing LS1 to go to logic "0". This causes LS1 to go to logic "1" at the input end of 175, which in turn resets the timing ramp generator, thus causing all timing signals T2, T3, T4 and T5 to go to logic "0". As a result 289 is closed, since 262 opens by de-energization of 260. However, 153 remains energized for a period of approximately 8 seconds (post-purge period), due to the delay network 302, 151, between the output LS1 and NAND gate 149, which controls 153 via resistor 303. This post-purge period helps to cleanse the combustion chamber at shut-down.

Various changes and additions may be made to the system as described without deviating from the invention, some of which will now be described.

PERMANENT PILOT

To obtain a system with a permanent pilot it would be necessary to remove signal $\overline{T5}$ from input 231 of 227.

PERMANENT PILOT PLUS HI/LO FUNCTION

To obtain this system signal $\overline{T5}$ is removed from input 231 of 227, a high limit stat would be fitted in lieu of thermostat 139, and a low temperature control would be fitted between the bi-directional thyristor 264 and fuel valve 289.

INTERMITTENT PILOT PLUS HI/LO

To obtain intermittent pilot plus HI/LO it would be necessary to fit a second fuel valve operated from relay contacts controlled by a relay switched from a parallel output of $\overline{T5}$. A low temperature control would be fitted between said relay contacts and fuel valve and the thermostat 139 would be replaced by a high limit stat.

MODULATION SYSTEM

For a modulating system an additional signal from T2 (FIG. 5) and a signal T5 (FIG. 6) are used to operate two relays, each of which controls a set of changeover contacts, the two sets of contacts controlling a modulating valve in the burner. This modulating valve controls the air and gas inputs to the burner. Two additional interlocks, similar to the air pressure checking system, would be incorporated to self-check the modulating valve at both high and low limits.

I claim as my invention:

1. An electronic programmer unit for a fuel burner for heating an enclosure, said programmer unit comprising:

flame monitor means for monitoring flame detection within said fuel burner and having "flame detected" and "no flame detected" outputs,

first transformer means for supplying electrical power to said flame monitor means,

control circuit means including switching control means for controlling switching of alarm means, burner motor means, ignition means for igniting fuel in the burner, pilot valve means for supplying pilot fuel in the burner and fuel valve means for supplying the main fuel to the burner,

voltage regulator means connected to said control circuit means,

second transformer means,

rectifier means connected to said second transformer means for supplying direct current voltage to said voltage regulator means,

said control circuit means including voltage ramp generating means comprising voltage generator means, voltage follower means for producing a uniformly linear output voltage in accordance with the voltage gradient produced by said voltage generator means and voltage comparator means for producing an output when said ramp voltage reaches a predetermined value,

operating relay means for controlling switching of said switch control means for said burner motor means, said ignition means, said pilot valve means and said fuel valve means,

a first plurality of gating means for controlling operation of said relay means,

first timing circuit means connected between the output of said voltage comparator means and said first plurality of gating means for controlling the time and sequence of operation of said operating relay means,

lockout means for shutting down the burner,

a second plurality of gating means for controlling actuation of said lockout means,

feedback means for connecting said second plurality of gating means to temperature sensor means for sensing the temperature of the enclosure to be heated, air pressure sensing means for sensing burner motor operation during purging, said flame monitor means, said ignition means, said pilot valve means and said fuel valve means,

second timing circuit means connected between the output of said voltage comparator and said second plurality of gating means,

and lockout reset switching means for resetting the programmer unit after lockout.

2. A programmer unit as claimed in claim 1, wherein said signal feedback means include a combination of neon lamp and photo-resistor.

3. A programmer unit as claimed in claim 1, wherein said voltage ramp generating means includes a capacitor charging circuit, including a capacitor, a constant current source, and associated resistive network, for charging said capacitor.

4. A programmer unit as claimed in claim 1, wherein said voltage comparator means comprises a pair of integrated circuit inverters with resistive feedback.

5. A programmer unit as claimed in claim 1, wherein said gating means comprise integrated circuit digital logic gates.

6. A programmer unit as claimed in claim 1, wherein said timing circuit means each comprise a capacitive-resistive diode network and a transistor amplifier.

7. An electronic programmer unit as claimed in claim 1, wherein said lockout means comprises a retentive memory electrically operated bistable means having set and reset operating coils, lockout indication means, inverter means, lockout signal means for producing a lockout signal, a lockout requirement operating changeover means for energizing said set operating coil to supply a ground return means for said lockout indication means and to remove a ground return means from said lockout signal means for changing a no lockout signal to a lockout signal through said inverter means and reset switch means for energizing said reset operating coil to remove said ground return means from said lockout indicating means and for operating said changeover means to convert said lockout signal to a no lockout signal through said inverter means.

8. An electronic programmer unit as claimed in claim 1, wherein said switching control means comprise bi-directional thyristors, the gate of said bi-directional thyristors being energized through contacts of relay means energized by outputs of said programmer.

9. An electronic programmer unit as claimed in claim 1, wherein said signal feedback means include a combination of neon lamp and photo-resistor, each named signal feedback means having neon lamp operatively connected to switching means external to said programmer, and a photoresistor operatively connected to gating means within said programmer, the output of said gating means being operatively connected to said lockout means.

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