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(71) Applicant: **International Business Machines Corporation, Armonk, N.Y. 10504 (US)**

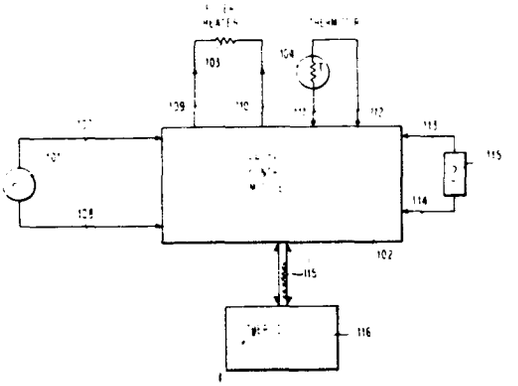
(72) Inventor: **Ernst, Larry Mason, 5000 Butte No. 35, Boulder, Colorado 80301 (US)**

(74) Representative: **Barth, Carl Otto, Dipl.-Ing. et al, Rablstrasse 24, D-8000 München 80 (DE)**

(54) Method and apparatus for operating a heat source in a reproduction machine.

(57) Method and apparatus for operating and regulating a heat soucre (103) in a reproduction machine, particularly for a fuser in a copier. The machine is operable in at least 3 modes, a warm-up, a stand-by, and a copy mode. The amount of energy supplied to the heat source (103) depends on the present mode of the machine and the actual temperature T of the fuser:

The supplied power is at level P1 during the warm-up mode until T ≥ T1 (T1 is a given temperature). Then, power is reduced to P2. In stand-by mode, power is increased to P2 + \ P1, if T < T2 (T2 is a given operating temperature), and decreased to P2 - \ P1, if T > T2. In the copy mode, power is increased to P2 + \ P2 if T < T2 and increased to P2 + Δ P3 if T ≥ T2.



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METHOD AND APPARATUS FOR OPERATING A HEAT SOURCE IN A REPRODUCTION MACHINE

The invention relates to a method and an apparatus including a microprocessor for controlling and regulating the electrical energy supplied to a heat source in a reproduction apparatus, e.g. a fuser in a xerographic or similar copying or printing machine.

In dry process xerographic reproduction machines, heat is often used to fuse the dry toner image to the supporting copy sheet before the copy is made available to the operator. Alternatively, in xerographic reproduction machines utilizing a wet developing process, heat is extensively used to dry the produced copy before it is fed to the output receptacle of the copying machine. For producing this heat, both radiant heating elements and devices using heat transfer by contact, e.g. hot roll fusers, are known. U.S. Patent No. 3,053,962, entitled "Xerographic Fusing Apparatus", to A. J. Cerasani et al and U.S. Patent No. 4,042,804, entitled "Roll Fuser Apparatus", to L. Moser show examples for different fusers.

A problem encountered in the design and utilization of copying machines employing heat fusing apparatus is the relatively large amount of thermal energy or the extended length of time required to fuse the toner to or dry the copy sheet. In dry xerographic processes, a heat fusing operation is relatively inefficient from a heat transfer standpoint and the heating unit must have sufficient

capacity to raise the temperature of the toner above its melting point as the copy sheet is moved through the fusing apparatus. Other significant and sometimes conflicting factors which enter into the design of heat fusing apparatus are the normal variations in ambient temperature and humidity and the character or density of the copy being fused. Also, any heat fusing apparatus has a thermal storage capacity and acts as a heat sink so that less power is required to fuse an image after it has been turned on for a period of time. The problems created by these conflicting design criteria become more critical as attemps are made to provide faster xerographic copying machines which rapidly produce a large number of quality copies and also provide the first copy in any copying run in the shortest possible time.

The control of xerographic fusing apparatus is addressed in U.S. Patent No. 3,532,855, entitled "Power Regulating Circuit for Xerographic Fusing Apparatus", granted October 6, 1970 to G. W. VanCleave. It discloses a circuit for regulating the power supplied to fusing apparatus employed to fuse images in a xerographic or similar copying machine. The circuit is operative to maintain a constant voltage across the heating element of the fusing apparatus under steady state operating conditions. A voltage feedback signal corresponding to the voltage across the heating element is sensed and used to control the firing angle of a thyristor or similar high capacity power supply device. The regulating circuit incorporates means for compensating for the difference between the average voltage and root mean square voltage whereby the power supplied to the heating element is maintained at a constant level under varying conditions. The circuit also automatically

increases the power to the fusing apparatus during the period when the first copies are being produced right after the copying machine has been turned on.

Another fusing control is disclosed in U.S. Patent No. 3,878,358, entitled "Digital Power Control", granted April 15, 1975 to E. D. Barton et al. It discloses a digital power control circuit for controlling the temperature of fuser apparatus in a xerographic copier in three different modes of operation. The circuitry utilizes digital logic principles and implements zero voltage switching of silicon controlled rectifiers. A thermistor is used as a temperature sensor. A voltage step generator provides eight voltage steps which are compared with the output of the thermistor. This comparison enables increments of power to be applied to the heat source, ranging from one-eighth to full power. Each increment of power is a full sine wave cycle and the silicon controlled rectifiers are switched so as to allow the determined number of power cycles to be applied to the heat source, depending upon the mode of operation and the temperature of the heat source.

U.S. Patent No. 3,961,236, entitled "Constant Power Regulator for Xerographic Fusing System", granted June 1, 1976 to V. Rodek et al discloses a constant power regulator for a xerographic fuser in which power control is achieved by taking the sum of the load voltage and current. The regulator includes an operational amplifier connected as a voltage adding circuit. The operational amplifier circuit of the power regulator adds the voltage drop across the fuser and a reference resistor connected in series with the fuser and the voltage drop across the fixed reference resistance which represents the current flow through the fuser. The output of this summing circuit is detected by a photodetector that electrically

isolates the power regulator from a voltage regulator which has an output for controlling the power supply to the fuser through, for example, a Triac, controlled as a function of the power supply signal and the detected voltage generated by the power regulating circuit.

Fuser apparatus employing a hot roll is also disclosed in US Patent No. 3,813516, entitled "Apparatus for Temperature Control for A Heated Rotating Cylinder" granted May 28, 1974, to B. S. Kudsi et al., and of common assignee with this application. The Kudsi patent discloses a method and apparatus for controlling the surface temperature of a heated roll in the hot roll fusing station. A web carrying the developed image is fed through the hot roll fusing station which comprises a heated feed roll mounted adjacent to a backing roll so that the developed image is fused to the web material. For proper operation the peripheral surface of the heated feedroll is maintained at an elevated temperature. A temperature sensing means, such as a thermistor, is mounted on suitable support means which positions the thermistor in the boundary layer surrounding the heated roll so that the changes in temperature in the boundary layer can be sensed. The output of the temperature sensing means comprises an electrical signal which is coupled to a temperature controller means to produce signals to control the amount of heat applied by the heating means to the heated feedroll to control its surface temperature.

However, in spite of the large number of known methods and apparatus the technical area of controlling temperature of and energy supply to a heating system in a

xerographic or similar copier or printer, is open to improvements, particularly when using microprocessors.

Thus, it is the primary object of this invention to provide an improved method for controlling the power supplied to a heat source in a reproduction machine, preferably in a fusing apparatus of a xerographic or similar copying or printing machine.

A more detailed object of the invention is to provide a microprocessor control method and circuit for the precision regulation of the electrical energy to the heat fusing apparatus of a reproduction machine.

A further object of the invention is to provide a microprocessor control circuit for efficiently providing precise increments of electrical energy to a fuser apparatus of a xerographic machine to bring and maintain said fuser apparatus to a desired temperature, where the desired temperature and increments of energy provided are in accordance with the mode of operation of the copier.

The invention as claimed is directed toward these objects. Particularly, claim 1 is directed to a method for operating an electrical heat source in a specific way, whereas claim 6 concerns an apparatus according to the invention.

One way of carrying out the invention will be apparent from the following more particular description of a preferred embodiment of the invention which is illustrated in the accompanying drawings:

Figure 1 is a schematic side view of an illustrative xerographic copy machine.

Figure 2 discloses the xerographic copying machine's overall controls with reference to fuser components.

Figure 3 shows a block schematic of the process control module 102 of Figure 2.

Figure 4 shows the AC line zero crossing circuit.

Figure 5 shows the safety relay and related circuitry.

Figure 6 shows the TRIAC driver circuitry.

Figure 7 shows the Wheatstone bridge circuitry.

Figure 8 shows the over-temperature fuse detection circuitry.

Figures 9A and 9B placed together disclose an operational flow chart.

Generally, a xerographic or similar reproduction machine, may be considered to operate in three separate modes. These modes may be termed "warm-up", "stand-by" and "print" or "copy" mode.

A copier is in its "warm-up" mode when it is initially turned on and the fuser temperature is brought up to a certain predetermined temperature level. The "stand-by" mode maintains the fuser temperature at the predetermined temperature level subsequent to the "warm-up"

mode and prior to the copier being activated to produce a copy or print. When the copier is called upon the produce a copy or print, the "print" mode is initiated. The "print" mode may raise the fuser temperature to a predetermined somewhat higher temperature level to effect fusing of toner particles onto a support sheet. by providing additional energy to the fusing apparatus. The support sheet is the xerographically produced print.

Referring now to the drawings and initially to Figure 1 thereof, there is shown a schematic representation of an illustrative xerographic copying machine. This machine corresponds essentially to the xerographic copier shown in U.S. Patent No. 3,532,885.

The electrophotographic member of the copying machine comprises a drum 10 which is mounted for rotation in the direction indicated by the arrow 11. Disposed on the outer periphery of the drum is photoconductor 12 coated on a flexible conductive backing material and stored on reels within the interior of the drum to permit replacement or changing of the operative photoconductor surface without removing the drum from the machine.

Disposed about the periphery of the drum 10 are a number of processing stations which carry out the conventional steps of the xerographic copying process. An initial charging station is provided by a corona unit 13 which deposits a uniform charge on the surface of the photoconductor 12 while the same is maintained in the dark. The next station is exposure station 14 where a line image of the original document is projected onto the uniformly charged surface of the photoconductor 12 as the drum 10 rotates.

The next station in the direction of the rotation of the drum 10 is cascade developer 20 where a two component developer composition is caused to cascade or move across the surface of the drum. The developer composition comprises heat fixable marking particles (toner) which are attracted to and deposited on the surface of the photoconductor 12 in accordance with the latent electrostatic image corresponding to the original. The result of the cascade development operation is the formation of a toner image on the photoconductor. It is necessary to transfer the toner image to a copy sheet and this is accomplished at the toner transfer station 22.

The plain copy paper is stored within the copying machine in roll form as indicated by roll 24 and is fed along a path of travel 25 in the direction indicated by the arrows leading past knives 26, toner image transfer station 22, fusing apparatus generally indicated by reference number 27 and then to an output copy hopper 28. The copy paper is cut to the length selected by the operator and the cut copy sheet moves into contact with the drum. A transfer corona unit 29 assists in the transfer of the toner image to the copy sheet. The copy sheet is then separated from the drum, the toner image fused by heat and the final copy transported to the output hopper 28.

Not all of the toner image is transferred to the copy sheet and it is necessary to remove the residual toner from the surface of the drum. This is accomplished by employing a pre-clean corona unit 30 whose corona discharge tends to loosen the remaining toner particles and a cleaning brush 31 which is rotated at high speed in the direction indicated by arrow 32. The toner

particles which are brushed from the surface of the photosensitive material are drawn by vacuum into a filter bag, not particularly shown, mounted within housing 33.

The fusing apparatus 27 is located along the upwardly inclined path of travel 25 of the copy sheets between the toner image transfer station 22 and the output copy hopper 28. It comprises a heating unit 34 and an elongated and stationary vacuum plenum 35 located below the path of travel 25 which provides a means for supporting and transporting copy sheets through the fusing apparatus. The heating unit 34 is positioned above the path of travel 25 of the copy sheets in opposed overlying relation with respect to the vacuum plenum 35 and comprises a quartz heating element or lamp 38 and a reflector 39. The lamp 38 and the reflector 39 are elongated and extend transversely across the path of travel 25 of the copy sheets. The inner surface of the reflector 39 is generally elliptical and highly specular. The heating lamp 38 and the reflector 39 cooperate to produce a transversely extending and relatively narrow band of infrared radiation on the surface of a copy sheet. The heating unit 34 is mounted from a carriage, not shown, for traversing movement back and forth along the path of travel of the copy sheets.

In operation, the heating unit 34 moves from the initial position to a final position indicated by broken lines as a copy sheet moves through the fusing apparatus along the path of travel 25. This arrangement effectively increases the time during which the copy sheet and the heating unit are in operative

fusing relation with respect to each other. After the fusing operation, the heating unit 34 is returned to its initial position. Additional details concerning the fusing apparatus are set forth in U.S. Patent No. 3,481,589, entitled "Xerographic Fusing Apparatus", granted December 2, 1969 to J. V. Cely et al.

The foregoing description of a representative xerographic copying machine and fusing apparatus is not intended to limit the present invention. The invention, with equal or greater utility and advantage, may be employed in xerographic copying machines varying in system configuration from the system above described and, in particular, xerographic copy machines utilizing fuser apparatus including a heated rotating cylinder, or hot roll.

In Figure 2, the xerographic copying machine's overall controls are very broadly depicted with more specific reference to certain electrical components associated with the fuser operation.

In Figure 2, a simplified schematic of the machine process control module 102 and its I/Os are shown. Block 116 is a general I/O representation of control areas (not expressly shown) such as the coronas, illumination lamp, developer bias, original pick, copy paper pick, etc. except for the areas related to the fuser control which is described in detail in this specification and the drawings.

Power input to the xerographic machine's process control module 102 is from the AC power source 101 via lines 107 and 108. Power is directed under the

control of process control module 102 to areas in the machine represented by I/Os in block 116 and fuser heater 103.

Thermistor 104 is a thermal energy to electrical resistance conversion device used to sense the temperature of the fuser or the fuser hot roll. The temperature information from thermistor 104 is conveyed via lines 111 and 112 to the process control module 102. Module 102 will interpret and apply the proper power level to the fuser heater 103 via lines 109 and 110.

Overtemperature fuse 115 is a further thermal energy to electrical value conversion element used to sense the fuser's temperature. The operating temperature of the overtemperature fuse 115 is set at a higher level than the nominal controlling temperature of the fuser. The process control module 102 will monitor lines 113 and 114 for continuous current flow; if this current flow should be reduced significantly (like 1/2 of nominal) the process control module 102 will assume the thermistor 104 and its related circuitry has malfunctioned (for example, the fuser's temperature has reached an excessive level). The process control module 102 will force itself into a failsafe condition preventing machine operation and removing all power to all I/O devices (block 116 and fuser heater 103).

Figure 3 shows a block schematic of the process control module 102. The basic timing element is the AC line zero crossing circuit 124. A pulse is generated on lines 118 and 142 everytime the output voltage of AC power source 101 crosses through zero potential. This pulse is inputted

into the TRIAC Driver 126 and the microprocessor 127. Line 130 applies an input signal to the overtemperature fuse detection circuit 129 to force the process control module 102 into a failsafe mode when the AC power source 101 changes to an abnormal low level.

Safety relay and related circuitry 125 is used to remove all power to all I/O devices when the process control module 102 senses a failsafe mode. The actual instruction controlling the safety relay is via line 119 from microprocessor 127.

TRIAC driver 126 is the power controlling element used to apply power to the fuser heater 103 at the proper time as determined by input lines 142 and 143. When line 143 is high from the microprocessor 127, power is applied to the fuser heater 103 for a half cycle of the AC power starting when a pulse is applied to line 142. Likewise, when line 143 is low, no power is applied to the fuser heater 103 independent of line 142.

The Wheatstone bridge 128 is used to interpret the thermistor's temperature information on lines 111 and 112. The microprocessor 127 varies lines 120 and 121 when it is necessary to check, per the instructions in the microprocessor's ROM, for one of the variations in temperature level on the fuser, as described later herein. Line 122 feeds the interpreted information into the microprocessor 127 after lines 120 and 121 have settled due to an internal delay from microprocessor 127.

The overtemperature fuse detection circuit 129 is used to interpret the temperature information on lines 113

and 114 (Figure 8). This information is inputted to the micropressor 127 via line 123. Anytime line 123 is high, the microprocessor 127 will force the process control module 102 into a failsafe mode. Due to the unique design of this overtemperature fuse detection circuit 129, two additional functions are also present as described below. When the machine is first turned on, an inherent delay is present which causes line 123 (Fig. 8) to go high for about 300 milliseconds due to the integration of resistors 69 and 70, capacitor 72, and Schmitt-Trigger 173 anytime the voltage on capacitor 72 is below the threshold voltage of the Schmitt-Trigger 173. The microprocessor 127 is forced to a certain predetermined location (initialization) in its ROM so the program starts from a known location (this location in the ROM is one of the process control module's 102 failsafe modes). The second function, by monitoring line 130, is to force the process control module 102 into a failsafe mode anytime the AC power source 101 drops to an unsafe voltage level.

Block 175 entitled "I/O Control" represents the other control circuitry used to control the I/Os in block 6 which represents other I/Os required for machine operation.

The microprocessor 127 may be any of the standard types available like the NEC u COM 45, Motorola 6800, TI TMS 1000, Rockwell MM 72, etc. (The foregoing names and type denominations are, at least partly, registered trademarks in one or more countries.) The purpose of the microprocessor 127 is to provide the process control module 102 with some minimal intelligence to ensure the I/O devices perform their necessary function.

Figures 4, 5, 6, 7 and 8 show the circuit schematics of the circuitry represented by blocks 124, 125, 126, 128 and 129, respectively, of Figure 3. The circuits per se are relatively simple and straightforward in operation and will be readily understood in view of the description hereinafter.

Figure 4 shows the AC line zero crossing circuit and 24 volt power supply. The power line voltage is stepped down by transformer 32 to the proper voltage for the 24 volt supply. The bridge 33 provides full wave rectification which may be used by transistor 73 to detect zero crossing when the current in resistor 35 approaches zero (voltage at the output of bridge 33 approaches zero). Diode 36 provides the necessary isolation between the 24 volt power supply and the zero crossing circuit. Capacitor 37 provides the necessary power supply filtering.

Figure 5 shows the safety relay and related circuitry. Driver 40 causes 24 Volt to be placed across the relay 41 coil when the signal on line 119 is high. The contacts of relay 41 close and power is applied to the TRIAC driver 126 and clock 175. When line 119 is low, the reverse of the above occurs.

Figure 6 shows the TRIAC driver. When line 143 is high and a pulse is applied to 142, driver 45 is turned on causing current to flow through the LED in module 46. This causes base drive to transistor 51, causing the TRIAC to be turned on. Components 47, 48, 53, 52 form a relatively simple power supply for the necessary current to gate the TRIAC on.

Figure 7 shows the Wheatstone bridge. Its basic function is to determine when thermistor 104 is above or below a certain resistance value. For example, when the thermistor 104 resistance is greater than 7.87kΩ (assuming resistors 58 and 61 are open), the plus input of operational amplifier 67 will be at a lower potential than the minus input causing the operational amplifier 67 to be low. This condition will cause line 122 to be high by inverter 68. If the condition described above is reversed, (i.e., thermistor 104 restistance less than 7.87kΩ) all signal levels are reversed.

Resistors 58 and 61 are used by the microprocessor by connecting lines 121 or 120 to a +10 volt power supply using internal drive transistor at the necessary time so different thermistor 104 resistance values may be checked.

Figure 8 shows the overtemperature fuse detection circuit. This circuit checks for current flow in overtemperature fuse 115. The current is supplied by resistors 69, 70 and 71 and capacitor 72. Schmitt trigger 173 is used to measure the voltage across resistor 71. Anytime this voltage is above 6 volts, line 123 will be low. Capacitor 72 is used for integration so noise does not cause line 123 to change levels very quickly and provide the necessary delay as described earlier.

Figures 9A and 9B show a partial flow chart of the program stored in the microprocessor's (127) ROM. The terms employed in the flow chart are defined in the following table.

Table of Terms Employed in Flow Chart
(Figures 9A and 9B)

P1 represents maximum power being provided to the heater 103 of the fuser apparatus. (Every full half cycle of power of the AC source).

P2 represents stand-by power being provided to the heater 103 of the fuser apparatus. (A predetermined number of half cycles of power of the AC source per unit of time wherein a greater number of half cycles of power are available within said unit of time).

ni represents the number of half cycles of power provided to the heater 103 of the fuser apparatus out of every sixteen, for example, half cycles (eight full cycles) of the AC power source.

n1 represents the number of half cycles of power provided to the heater 103 of the fuser apparatus out of every sixteen, for example, half cycles (eight full cycles) of the AC power source to maintain the fuser apparatus in the stand-by mode, i.e. fuser temperature T2.

n2 represents the incremental, or additional, number of half cycles of power added to n1 and provided to the heater 103 of the fuser apparatus out of every sixteen, for example, half cycles (eight full cycles) of the AC power source when the fuser apparatus is in a copy mode (print mode) and the temperature of the fuser is less than the temperature T2.

n3 represents the incremental, or additional, number of half cycles of power added to n1 and provided to the heater 103 of the fuser apparatus, out of every sixteen, for example, half cycles (eight full cycles) of the AC power source when the fuser apparatus is in a copy mode (print mode) and the temperature of the fuser is equal to or greater than temperature T2.

T1 is the up-to temperature of the fuser roll or the fusing apparatus when it is in the warm-up mode.

T2 is the operating temperature of the fuser roll or the fusing apparatus when it is to be utilized during the copy mode (print mode) or stand-by mode.

X2 represents the time period during a copy cycle when additional energy must be provided to the heater 103 of the fuser apparatus to compensate for the heat loss attributable to the actual fusing operation of the toner to the copy. This is particularly important when a hot roll fuser is used.

The portion of the flow chart shown in Figures 9A and 9B specifically relates to the toner fusing operation and, in particular, temperature control of the fuser hot roll. To understand the flow chart details better, assume the process control module 102 is initially powered by the AC power source 101. Line 123 (Figure 3) will be held high for a period while capacitor 72 (Figure 8) charges. During this time the microprocessor's 127 program will be held at a fixed location which causes the process control module 102 to be in a failsafe mode.

After capacitor 72 charges, line 123 changes to a DOWN level with the microprocessor 127 cycling through its program after the first initial zero crossing pulse on line 118. The microprocessor 127 turns the fuser heater 103 on at full power. The basic action while the fuser temperature is less than T1 (line 120 held high with line 121 open circuit and line 122 remaining high from the instructions of the microprocessor 127, whereby the Wheatstone bridge measures T1) is to prevent the machine from making copies. This control (precluding the machine from entering the copy mode) is exercised by microprocessor 127 through control circuitry (block 175, Figure 3; block 116, Figure 2) not expressly shown herein. After the microprocessor 127 checks for other necessary machine functions, it returns to the beginning of the program and halts. After the next zero crossing, the microprocessor 127 will repeat the above cycle.

When the microprocessor 127 senses that the fuser temperature has exceeded temperature T1, it will automatically reduce the input power level to fuser heater 103 from P1 to P2. This allows the fuser temperature to reach the correct operating point without excessive overshoot due to the thermal lag associated with the fusing pararatus, particularly when using a hot roll. While the machine is in "stand-by", the process control module 102 constantly monitors the fuser temperature to maintain the proper temperature T2. This is accomplished by varying n1 at the proper rate to ensure the proper amount of energy is supplied. For example, if the fuser temperature is low as determined by the Wheatstone bridge 128, the microprocessor will increase n1 by one. It will maintain this value for a predetermined time

period to see if the fuser temperature increases, i.e. responds as expected. If not, the microprocessor 127 will increase n1 (after a predetermined time delay) until the fuser temperature T2 is exceeded. Similarly, when the fuser temperature is too high, the reverse process described is performed. Namely, n1 will be reduced to thereby provide less energy to the fuser. Also during this time, processing power of the microprocessor 127 is multiplexed to monitor other I/O devices (blocks 116 and 175) ensuring their proper function.

Periodically, for example every 30 seconds, the microprocessor 127 will bring line 121 high for about 20 milliseconds, so resistor 58 (Figure 7) will be in parallel with resistor 59 (resistor 61 is open circuit). This will cause the output line 122 to determine if the fuser temperature is at an excessive level (additional safety feature to the overtemperature fuse). If so, the microprocessor 127 enters a state called hard stop (similar to the failsafe mode) preventing machine operation and dropping all power to all I/O devices via the safety relay 141 (Figure 5).

When the process control module 102 senses the machine is asked to produce a copy, the process control module 102 causes the I/O devices (block 116) to operate in the proper sequence. In addition, the process control module 102 changes the power level in fuser heater 103 at the proper time in the copy process sequence. From experimental studies, one finds that approximately 500 joules are required to fuse toner to an 8-1/2 by 11 inches sheet of paper using a hot roll fuser. To minimize the temperature

excursions between the time the fuser is in stand-by and the time the fuser is fusing toner to paper, the rate energy is removed and the rate energy must be replaced should be the same. For example, the standby losses of the fuser remain relatively constant over any given environment, therefore, all that is necessary is a system which responds to find the optimum rate at which energy may be replaced in the fuser. But when paper enters the fuser, the paper acts very much like a heat sink removing energy at a very rapid rate; therefore, it is necessary to increase the rate energy is provided to the fuser to match the removal rate. A very simple method is to increase the power to fuser heater 103 by a fixed amount for a certain duration about the time paper is entering the fuser hot roll nip. The optimum time would be about one thermal time constant of the fuser hot roll immediately before the paper enters the fuser. This is accomplished by the microprocessor 127 adding a fixed number (n2 or n3) to n1 depending upon the fuser hot roll's temperature for the duration the hot roll fuser needs additional energy. For example, if the fuser hot roll's temperature is less than T2, the fixed number n2 added to n1 will cause the power in fuser heater 113 to be slightly greater than the standby losses and energy required for fusing. Similarly, the number n3 added to n1 when the fuser hot roll's temperature is greater than T2, will be slightly less than the standby losses and energy required for fusing.

It should also be noted, if the fuser's standby losses are relatively constant over all environmental conditions, it is possible to reduce the amount of

programming required in the microprocessor 127. This is accomplished by setting n1 equal to one of two values depending upon the fuser hot roll's temperature (one when the fuser is below T2, and one when fuser is above T2) instead of letting the microprocessor find the optimum value of n1, as described supra for the standby losses.

Referring to the flow chart of Figures 9A and 9B, a further detailed explanation of the operation of the microprocessor controlled power supply for xerographic fusing apparatus in accordance with the invention is set forth hereinafter.

Referring to Figure 9A, block 201 represents the turning on of the xerographic machine, namely the initial application of power to the machine (see power source 101, Figure 2).

Referring to circle 202 and blocks 203, 204 and 205, full power is provided to the fuser heater of the fusing apparatus subject to the following conditions. The logical condition required by circle 202 is that the power to the xerographic machine has just been turned "on" and/or the fuser temperature is less than a predetermined temperature T1.

Block 203 entitled "Hold Till Zero Crossing" represents the condition that only full half cycles of power will be provided to the fuser heater. (Reference is made to AC line zero crossing circuit 124, microprocessor 127, and Triac driver circuit 126, Figure 3).

Block 204 entitled "Machine Function Check Except Fuser" represents the condition that in addition to the fuser temperature all other xerographic machine functions are monitored by the microprocessor 127. The monitoring of these functions such as paper supply, corona unit, etc., as to their ready state, or status, by the microprocessor is not explicitly disclosed herein. Block 204 represents that none of these functions provides a manifestation to the microprocessor directing it to preclude by control the application of power to the heater of the fusing apparatus. Block 205 entitled "Turn Fuser Heater On to Full Power P1" represents the following status: (1) the fuser roller of the fusing apparatus is below temperature T1 (the xerographic machine has just been turned on, or the temperature of the fuser has not yet reached T1); (2) the conditions as represented by blocks 203 and 204 have been and are being met; (3) and full power is being applied to the heater of the fusing apparatus. Full power P1 being defined as in the table supra to be each and every half cycle of power available from the AC power source.

Reference is made to diamond shaped decision block 206 entitled "Check Fuser for Temperature T1". This block represents the fact that the fuser is continually monitored for the temperature T1. The block 206 may be considered a decision block in the flow chart. As long as the temperature is below T1, maximum power will be provided to the fuser heater. This condition is depicted by the legend "No" associated with feedback line 206B. Still referring to block 206, when the temperature is equal to or greater than T1 the condition is depicted by the legend "Yes" associated with line 206A which manifests this condition to

block 207 in the flow chart. Block 207 entitled "Reduce Fuser Heater Power to P2 (ni=n1)" represents the fact that once the temperature of the fuser reaches T1, in response to the application of maximum power, the power provided to the fuser heater is reduced from P1 to P2. Power P2, as defined earlier herein, is stand-by power, wherein a predetermined number of half cycles of power of the AC source per unit of time (wherein a greater number of half cycles of power is available from said source within said unit of time) are provided to the fuser heater of the fusing apparatus.

Block 208, entitled "Set Machine Status From Warm-Up to Stand-By" indicates that the xerographic machine is in condition to be called upon to function to produce copies or prints. Namely, the machine is ready, including the temperature of the fuser apparatus, for a copy cycle to be initiated.

Referring to circle 209 the logical condition required is (1) an output from block 209 that the machine status has changed from the warm-up mode to the stand-by mode, or (2) output from block 223 representing machine has completed fusing operation in a copy cycle, or is maintaining stand-by mode. The block 210 entitled "Hold Till Zero Crossing" contained within the flow chart closed loop of blocks 210 through 223 corresponds in the condition represented to the like entitled block 203 contained with the flow chart closed loop of blocks 203 through 206. The decision block 211 entitled "Check Fuser Over-Temperature Every 24 Minutes", represents the fact that the overtemperature detection means of the fuser apparatus is being continually monitored. (Reference is made to block 129,

Figure 3, and to the circuit of Figure 8). If the fuser temperature is out of range, namely too high, this condition is manifested by a "Yes" condition on line 211A and conveyed to block 212 entitled "Hard-stop". Referring to blocks 211 and 212, when the temperature of the fuser apparatus is too high , i.e. outside an acceptable high limit, the machine is brought to a "hard stop". This means that the power to the machine is automatically interrupted. Assuming the xerographic machine's fuser apparatus temperature is not too high, i.e. not above said high temperature limit, this condition is depicted on the flow chart of Figure 9b as a "No" manifestation and conveyed from block 211 to 213.

Decision block 213 entitled "Check for Copy" represents the provision of a "No" condition on line 213B when the machine is not called upon to produce a copy (enter a copy cycle) and provides a "Yes" condition on line 213A when the machine is called upon to produce a copy (enter a copy cycle).

For purposes of discussion assume the overtemperature check (block 211) is negative, and the "Check For Copy" (block 213) is negative, then the operation will proceed to the function represented by block 218, namely "Other Machine Function Checks". The "Other Machine Function Checks" are a monitoring by the microprocessor of the paper supply, toner supply, potential levels in the machine circuitry, the corona unit, etc. Assuming the machine function checks are positive, the operation proceeds to check the fuser temperature to determine whether the temperature of the fuser is greater than or equal to T2 or less than

T2. This is executed by decision block 219 entitled "Check Fuser for Temperature T2". Assume the temperature of the fuser is T2 or slightly greater, this condition is indicated by a "Yes" on line 219A from block 219, and the operation proceeds to the function depicted by block 220. Block 220 is entitled "Decrease n1 by 1 if Proper Delay Since Last Change". The function represented by block 220 is a reduction of 1 in n1, where n1, as defined earlier herein, represents the number of half cycles of power provided to the heater 103 of the fuser apparatus out of every sixteen, for example, half cycles (eight full cycles) of the AC power source to maintain the fuser apparatus (temperature T2) in the stand-by mode. If the specified time interval since the last change in n1 has not elapsed, then n1 will not be decreased.

Now referring back to decision block 219 entitled "Check Fuser For Temperature T2", assume the temperature of the fuser is less than temperature T2. This condition is indicated in the flow chart by a "No" on line 219B from block 219 and the operation proceeds to the function depicted by block 221 in the flow chart. Block 221 is entitled "Increase n1 by 1 If Proper Delay Since Last Change". The function represented by block 221 is an increase in n1 where n1, as defined supra, is a number of half cycles of energy supplied to the fuser apparatus. Again, if the specified time interval since the last change in n1 has not elapsed, then n1 will not be increased.

Now, still referring to the flow chart of Figure 9B, assume the xerographic machine is in the stand-by mode and is called upon to produce a copy. Further

assume the fuser apparatus overtemperature check is negative (block 211). Then the "Check for Copy" function in the flow chart represented by block 213 will manifest a positive condition (namely as indicated in the flow chart as "Yes" condition on line 213A) to block 214, entitled "Other Machine Function to Produce Copy". The functions represented by block 214 is the initiation of requisite machine functions other than fuser temperature and energy thereto necessary to produce a copy. These functions are well known to the art and include, for example, the functions of paper feed, corona unit energization, image exposure, toner feed, etc. Then, operation proceeds to the function represented by decision block 215 entitled "Check Fuser for Temperature T2". Assume the temperature of the fuser is T2 or slightly greater. This condition is indicated by a "Yes" on line 215A from block 215 and operation proceeds to the function depicted by block 216. Block 216 is entitled "Add n3 To n1 For X2 Seconds Then Return To n1". The function represented by block 216 is an increase in the number of half cycles of energy per unit time provided to the fuser apparatus for a given number of units of time where the total elapsed time of the given number of units of time is in the order of X2 seconds. Where n1, n3 and X2 are defined as follows: n1 represents the number of half cycles of power (energy) provided to the heater 103 of the fuser apparatus out of every sixteen, for example, half cycles (eight full cycles) of the AC power source to maintain the fuser apparatus in the stand-by mode (temperature T2); n3 represents the incremental, or additional, number of half cycles of power (energy) added to n1 and provided to the heater 103 of the fuser apparatus, out of every sixteen, for example,

half cycles (eight full cycles) of the AC power source, when the fuser apparatus (temperature T2) is in a copy cycle (print mode) and the actual temperature of the fuser is equal to or greater than temperature T2; and X2 represents the time period during a copy cycle when additional energy must be provided to the heater 103 of the fuser apparatus to compensate for the heat loss attributable to the actual fusing operation.

Now, still assuming the same conditions namely: the xerographic machine is in the stand-by mode or has just completed a copy cycle; the fuser apparatus overtemperature is negative (block 211); the machine has been called upon to produce a copy or copies (block 213); and the function represented by block 214 has been initiated. Referring to block 215, and as distinguished from the earlier discussion, assume that the "Check For Temperature T2" indicates that the fuser temperature is less than T2. This condition is indicated in the flow chart by a "No" condition on line 215B and the operation proceeds to the function represented by block 217, namely "Add n2 To n1 For X2 Seconds Then Return To n1". The function represented by block 217 is an increase in the number of half cycles of power per unit time provided to the fuser apparatus for a given number of units of time where the total elapsed time of the given number of units of time is in the order of X2 seconds, where n2 is the incremental or additional number of half cycles of power added to n1 out of, e.g., every sixteen half cycles of the AC power source, when the machine is in a copy cycle and the fuser temperature is lower than T2. The values of n1, n3 and X2 are as

defined earlier herein. It is to be appreciated that n2 > n3; and hence n1+n3 < n1+n2.

Still referring to Figure 9B, it will be seen that the flow proceeds in parallel from one of the blocks 220, 221, 217 and 216 to the logical connective represented by circle 222 and, therefrom to block 223 entitled "Set Fuser Power Level As Determined by Above". The function of block 223 is further depicted in flow chart by lead 223A interconnecting said block with the logical connective represented by circle 209 (Fig. 9A).

It will now be apparent that in the flow chart of Figures 9A and 9B the operation of the microprocessor controlled power supply for a xerographic fusing apparatus in accordance with the invention functions in three major modes, with two of these major modes each having first and second lesser modes. With reference to the flow chart of Figures 9A and 9B these modes are summarized below.

Warm-up Mode: The closed loop operations and functions represented by legends and symbols bearing reference characters 202, 203, 204, 205 and via line 206B to 202.

Stand-by Mode: The closed loop operations and functions represented by legends and symbols bearing reference characters
(I) (Fuser Temperature is equal to T2 or slightly greater): 209, 210, 211, 213, 218, 219, 220, 222, 223 and via line 223A to 209;
(II) (Fuser Temperature is less than T2): 209, 210, 211, 213, 218, 219, 221, 222, 223 and via line 223A to 209.

Copy Mode (Print Mode): The closed loop operations and functions represented by legends and symbols bearing reference characters

(I) (Fuser Temperature is equal to T2 or slightly greater): 209, 210, 211, 213, 214, 215, 216, 222, 223 and via line 223A to 209;

(II) (Fuser Temperature is less than T2) 209, 210, 211, 213, 214, 215, 217, 222, 223 and via line 223A to 209.

It will be apparent that the microprocessor controlled power supply for xerographic fusing apparatus, in accordance with the invention, provides during the stand-by mode and the copy mode the monitoring of the temperature of the fuser apparatus and the control of the energy increments per unit time provided to the fuser apparatus in a manner which approaches actual real time continuous fuser temperature control.

It is to be appreciated that although in disclosing and describing the preferred embodiment of applicant's invention, a number of commercially available components are shown in the drawing with accompanying commercial part numbers, for example, Motorola MDA1004 (Fig. 4), Arrow HC2-P (Fig. 5), Motorola MC1416P (Figs. 5 and 6), Motorola 4N35A (Fig. 6), RCAT2710D (Fig. 6), etc., applicant's invention is not limited, nor to be so construed as limited, to these particular components. Numerous suitable components known to the art and commercially available may be employed to practice the invention.

Further, although a specific commercially available microprocessor is disclosed herein earlier, as em-

ployed in the preferred embodiment of applicant's invention, the art is fully conversant with a number of commercially available microprocessors which may be employed to practice applicant's invention. Representative are the following: NEC u Com 45, Motorola 6800, TI TMS 1000, Rockwell MM 75.

It shall again be pointed out that the above names and type denominations are, at least partly, registered trademarks in one or more countries.

Reference is also made to the following publications: "An Introduction to Microprocessors", Copyright 1975 by Adam Osborne and Associates Incorporated, Published by Adam Osborne and Associates Incorporated, 2950 Seventh Street, Berkeley, california 94710, U.S.A.; "Understanding Microprocessors" by The Staff of Motorola Inc., Semiconductor Products Division, (based on the series "Understanding Microprocessors" published by Electronics Weekly), published by Motorola Semiconductors; "Pace Technical Description", Integrated Microprocessor IPC-16, June 1975, Copyright by National Semiconductor Corporation, 2900 Semiconductor Drive, Santa Clara, California 95051, U.S.A.; AMI 6800 Microprocessors by American Microsystems, Inc., 3800 Homestead Road, Santa Clara, Ca.95051, U.S.A.; and "Microcomputers/Microprocessors: Hardware Software and Applications" by J. L. Hilburn and P. M. Julich, Prentice-Hall Series in Automatic Computation, Copyright 1976, published by Prentice Hall.

While the invention has been particularly shown and described with reference to a preferred embodiment thereof, it will be understood by those skilled in

the art that the foregoing and other changed in form and details may be made therein without departing from the spirit and scope of the invention.

C L A I M S

1. Method of operating an electrical heat source (103) for a sheet treating device (27) in a reproduction machine, particularly for a fusing device of a xerographic reproduction machine (Fig. 1), said reproduction machine being operable in a plurality of different modes, including a warm-up, a stand-by, and a print mode,

characterized in

that the amount of energy supplied to the heat source (103) is at a first level P1 during the warm-up mode until the sheet treating device (27) reaches a first given temperature T1,

that, subsequently, the amount of energy supplied to the heat source (103) is reduced to a second level P2, $P2 < P1$,

that in the stand-by mode the level P2 of supplied energy is increased to $P2 + \Delta P1$ if the actual temperature T of the sheet treating device (27) is smaller than a given temperature T2, $T < T2$, and is decreased to $P2 - \Delta P1$, if $T = T2$, and

that in the print mode the level P2 of supplied energy is increased to $P2 + \Delta P2$, if $T < T2$, and increased to $P2 + \Delta P3$, if $T \geq T2$.

2. Method according to claim 1, wherein, in the stand-by mode, the change of the level P2 of supplied energy to P2 $\pm \Delta$ P1 is executed only if a given time interval has passed since the last change.

3. Method according to claim 1, wherein, in the print mode, the level P2 of supplied energy is incremented to P2 + Δ P2 or P2 + Δ P3, respectively, for a given time interval, and decremented to P2 after said given time interval has passed.

4. Method according to claim 1, further including the steps of comparing the temperature T of the sheet treating device (27) with a given maximum temperature T3, and, if $T \geq T3$, of switching off the heat source (103).

5. Method according to claim 1, wherein the method steps are started and executed periodically with a frequency of between 50 Hz and 120 Hz.

6. Apparatus for carrying out the method according to one or more of the preceding claims, said apparatus including in a reproduction machine (Fig. 1) being operable in a variety of different modes, electrical heater means (103) in a fusing device (27), control means (126) for providing electrical energy to said heater means (103), and temperature sensing means (104, 128) for providing an electrical representation of the fuser device (27) temperature,

characterized in

that the control means (102) includes a microprocessor (127) connected to the temperature sensing means (104, 128), to the electrical energy control means (126), and to the reproduction machine (Fig. 1) for controlling the amount of electrical energy provided to the heater means (103) depending on the operational mode of the reproduction machine (Fig. 1) and the electrical representation of the fuser device (27) temperature in accordance with at least one method step as defined in one or more of the preceding claims.

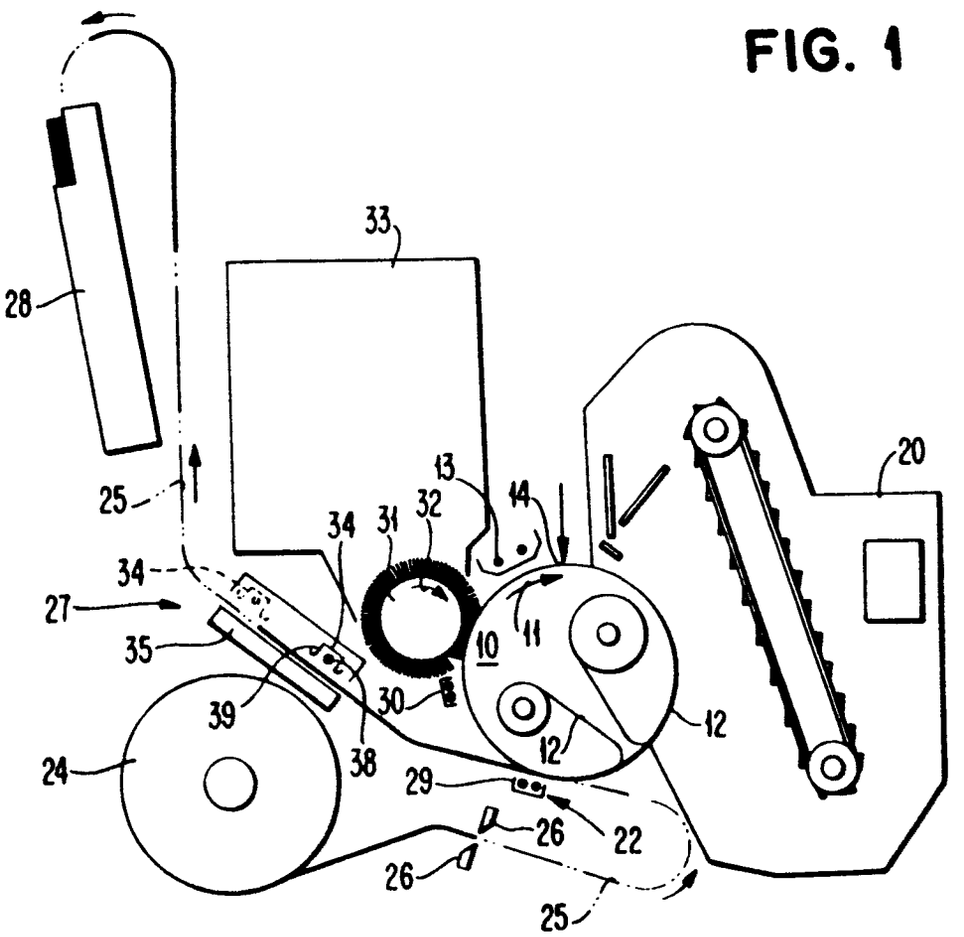
7. Apparatus according to claim 6, wherein the fusing device (27) is a hot roll fuser.

8. Apparatus according to claim 6, wherein the heater means (103) includes an incandescent lamp, particularly a quartz-iodine lamp.

9. Apparatus according to claim 6, wherein the temperature sensing means includes a thermistor (104) forming one leg of a Wheatstone bridge (128), the output of which is connected to the microprocessor (127).

10. Apparatus according to claim 6, further including overtemperature detection means (115, 129) rendering a signal to the microprocessor (127) when the temperature of the fusing device (27) reaches a predetermined temperature.

FIG. 1


33
28
25
34
31
32
13
14
20
34
27
35
10
11
39
30
12
12
24
38
29
26
22
26
25

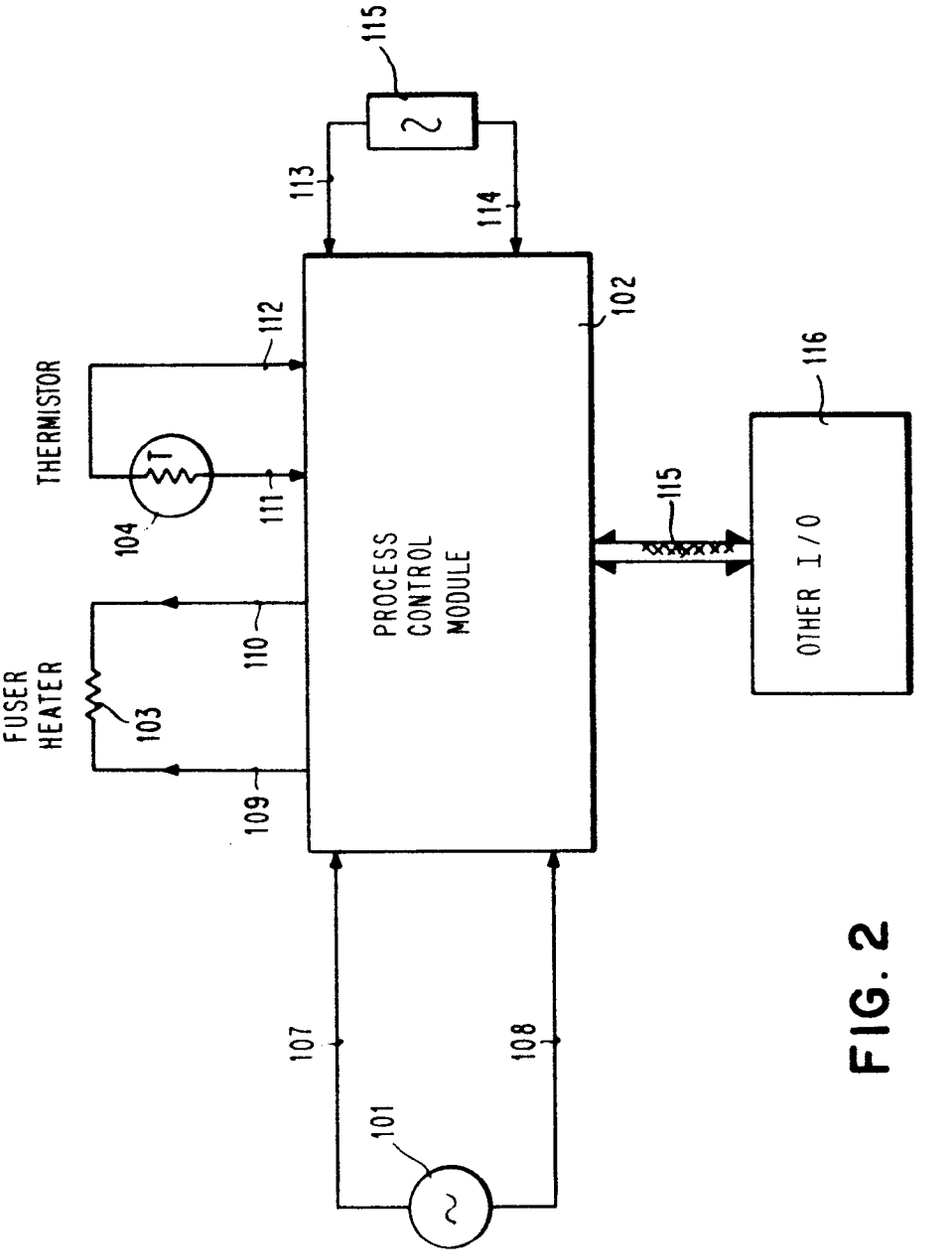

115
2
113
114
102
112
THERMISTOR
T
104
111
116
115
OTHER I/O
PROCESS CONTROL MODULE
110
FUSER HEATER
103
109
107
108
101

FIG. 2

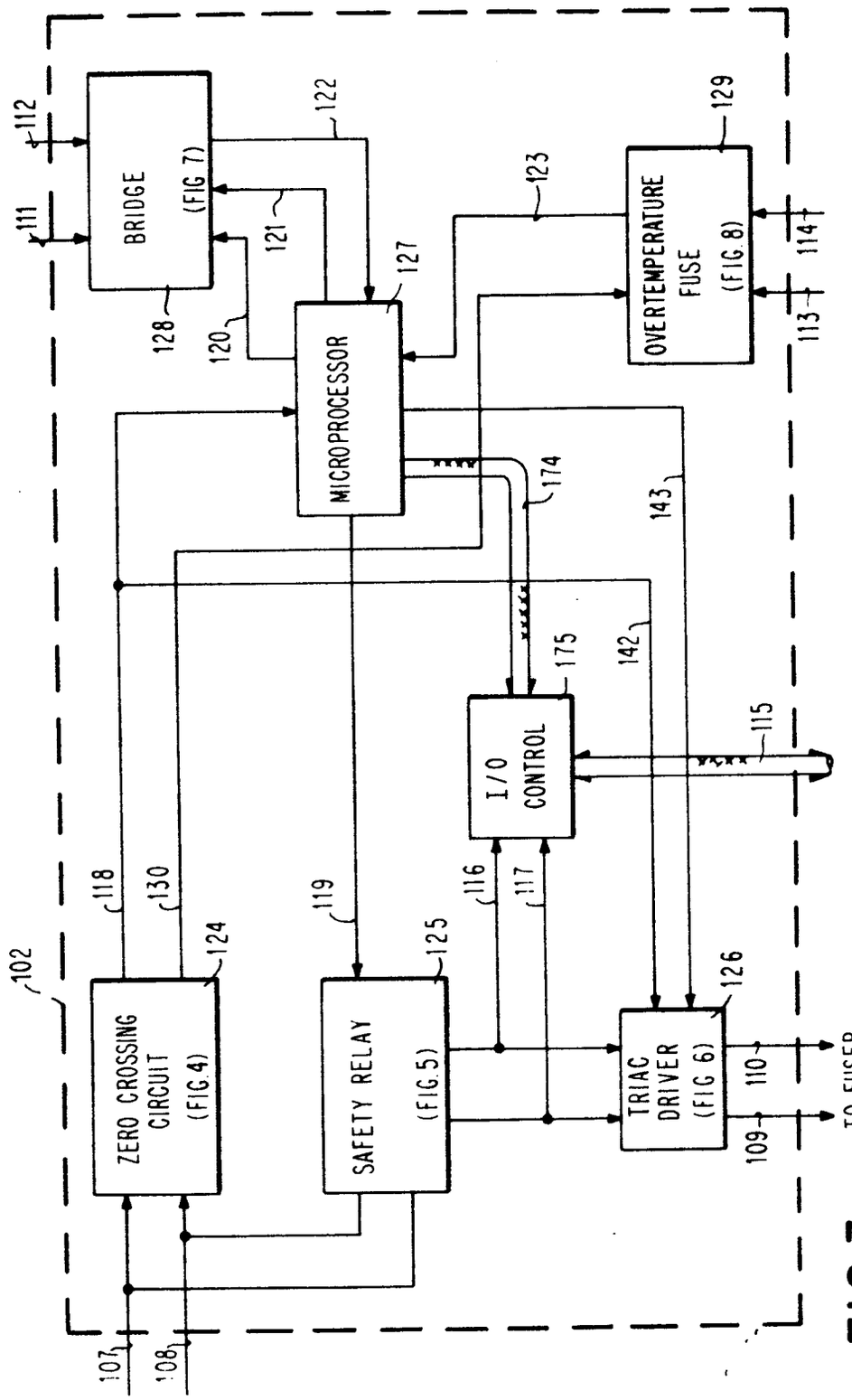

BRIDGE (FIG 7)
MICROPROCESSOR
OVERTEMPERATURE FUSE (FIG 8)
I/O CONTROL
ZERO CROSSING CIRCUIT (FIG 4)
SAFETY RELAY (FIG 5)
TRIAC DRIVER (FIG 6)
TO FUSER (FIG 2)
102
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
142
143
174
175

FIG.3

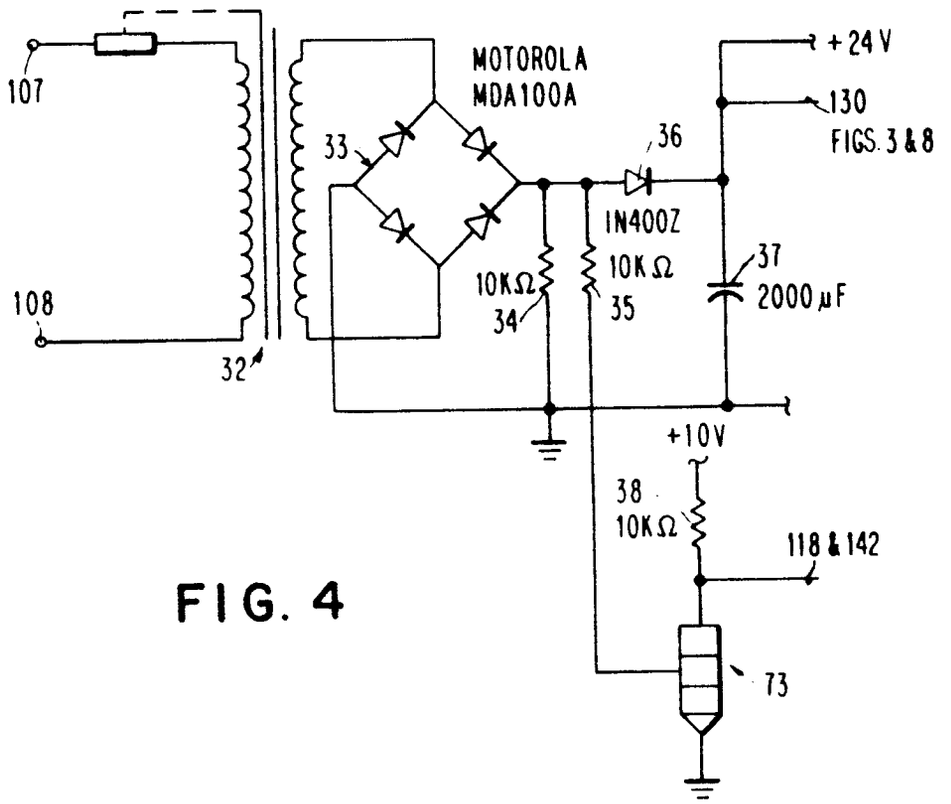

107
108
32
33
MOTOROLA
MDA100A
36
IN400Z
+24V
130
FIGS. 3 & 8
10KΩ
34
10KΩ
35
37
2000μF
+10V
38
10KΩ
118 & 142
73

FIG. 4

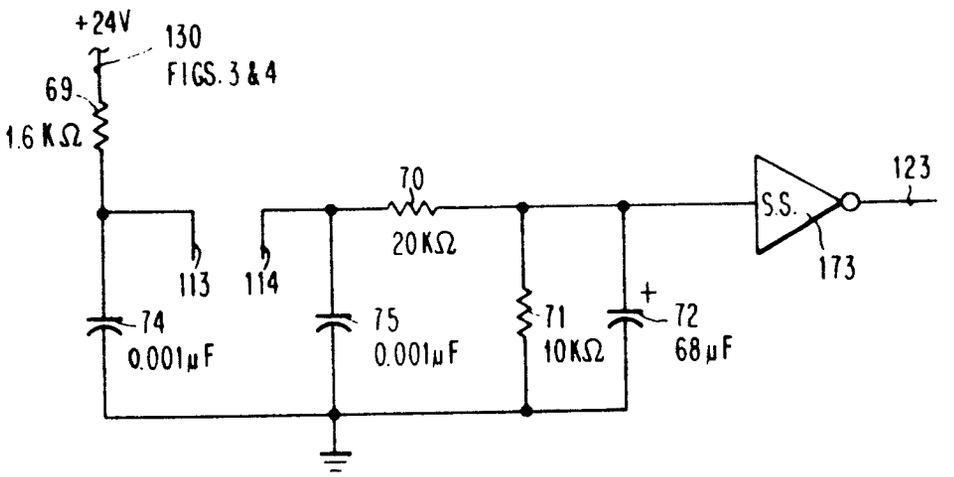

+24V
130
FIGS. 3 & 4
69
1.6KΩ
70
20KΩ
S.S.
123
173
113
114
74
0.001μF
75
0.001μF
71
10KΩ
72
68μF

FIG. 8

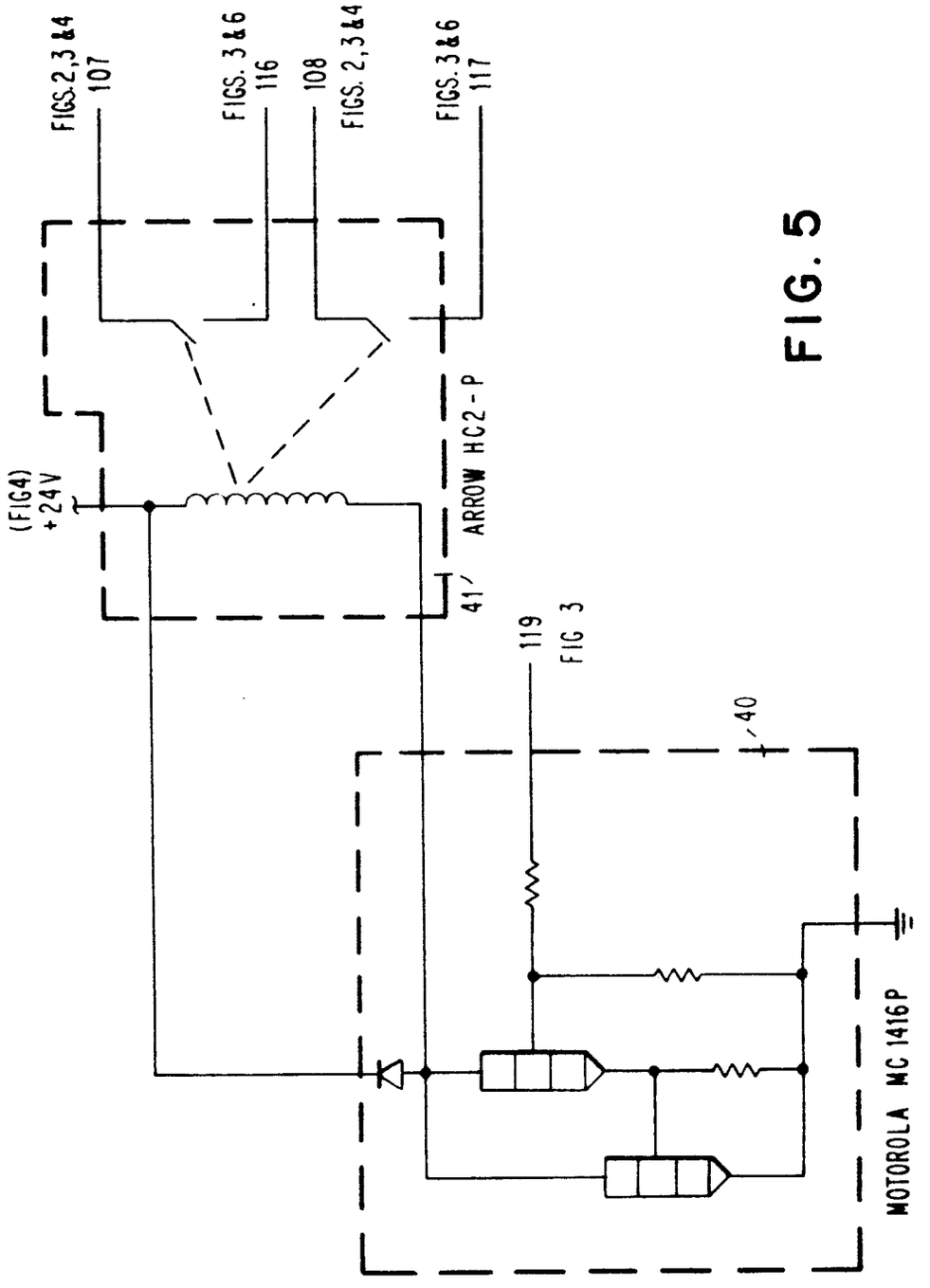

FIGS.2,3 &4
107
FIGS. 3 &6
116
108
FIGS. 2,3 &4
FIGS.3 &6
117
(FIG4)
+24V
ARROW HC2-P
41
119
FIG 3
40
MOTOROLA MC 1416P

FIG. 5

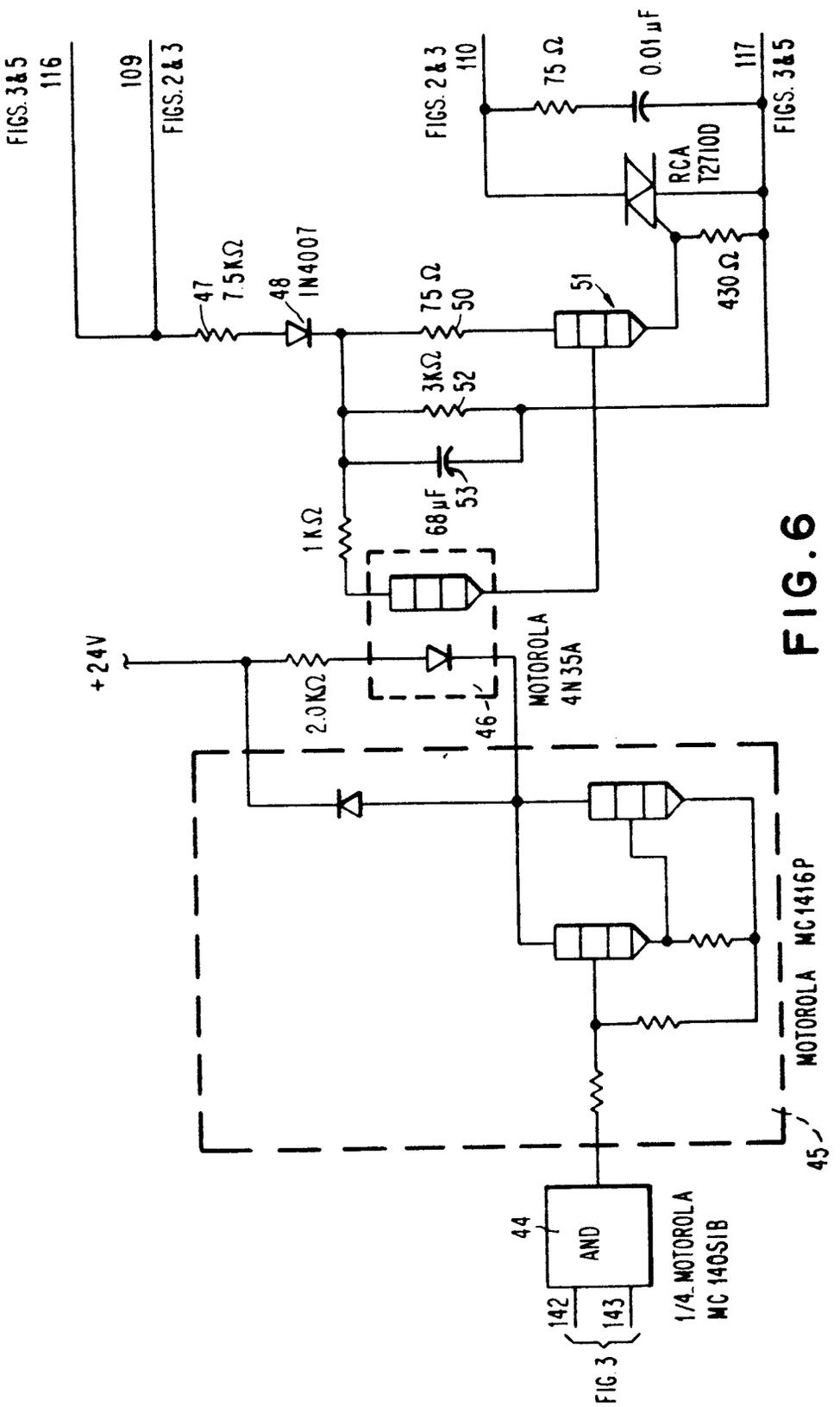

FIGS. 3&5
116
109
FIGS. 2&3
FIGS. 2&3
110
75 Ω
0.01 µF
117
FIGS. 3&5
RCA
T2710D
47
7.5KΩ
48
IN4007
75 Ω
50
51
430 Ω
3KΩ
52
68 µF
53
1 KΩ
+24V
2.0KΩ
46
MOTOROLA
4N35A
MOTOROLA MC1416P
45
44
AND
142
143
FIG 3
1/4 MOTOROLA
MC 14081B

FIG.6

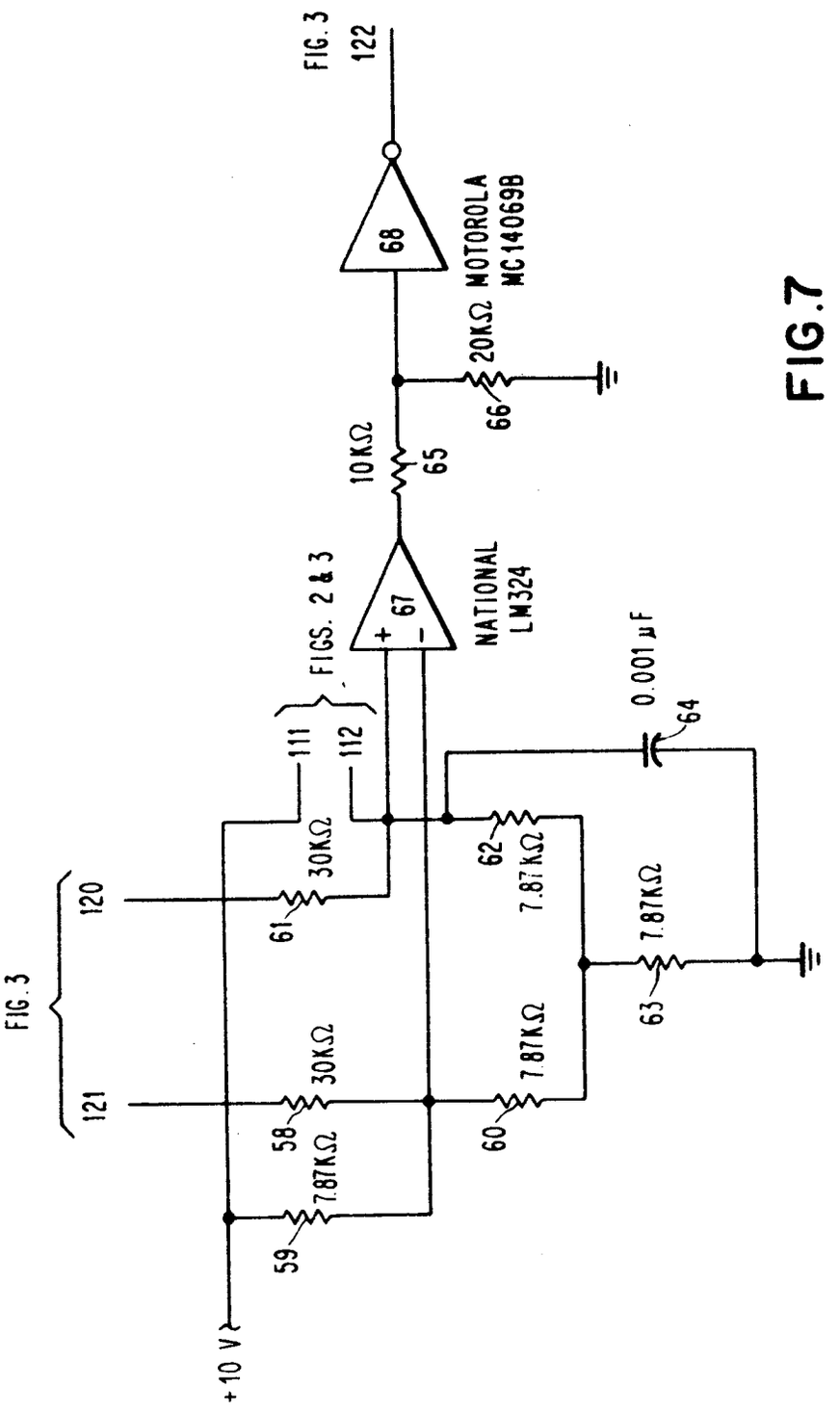


FIG. 3
122
68
MOTOROLA
MC14069B
20KΩ
66
10KΩ
65
FIGS. 2 & 3
67
NATIONAL
LM324
0.001 μF
64
111
112
120
30KΩ
61
62
7.87KΩ
7.87KΩ
63
FIG. 3
121
30KΩ
58
7.87KΩ
59
7.87KΩ
60
+10 V

FIG.7

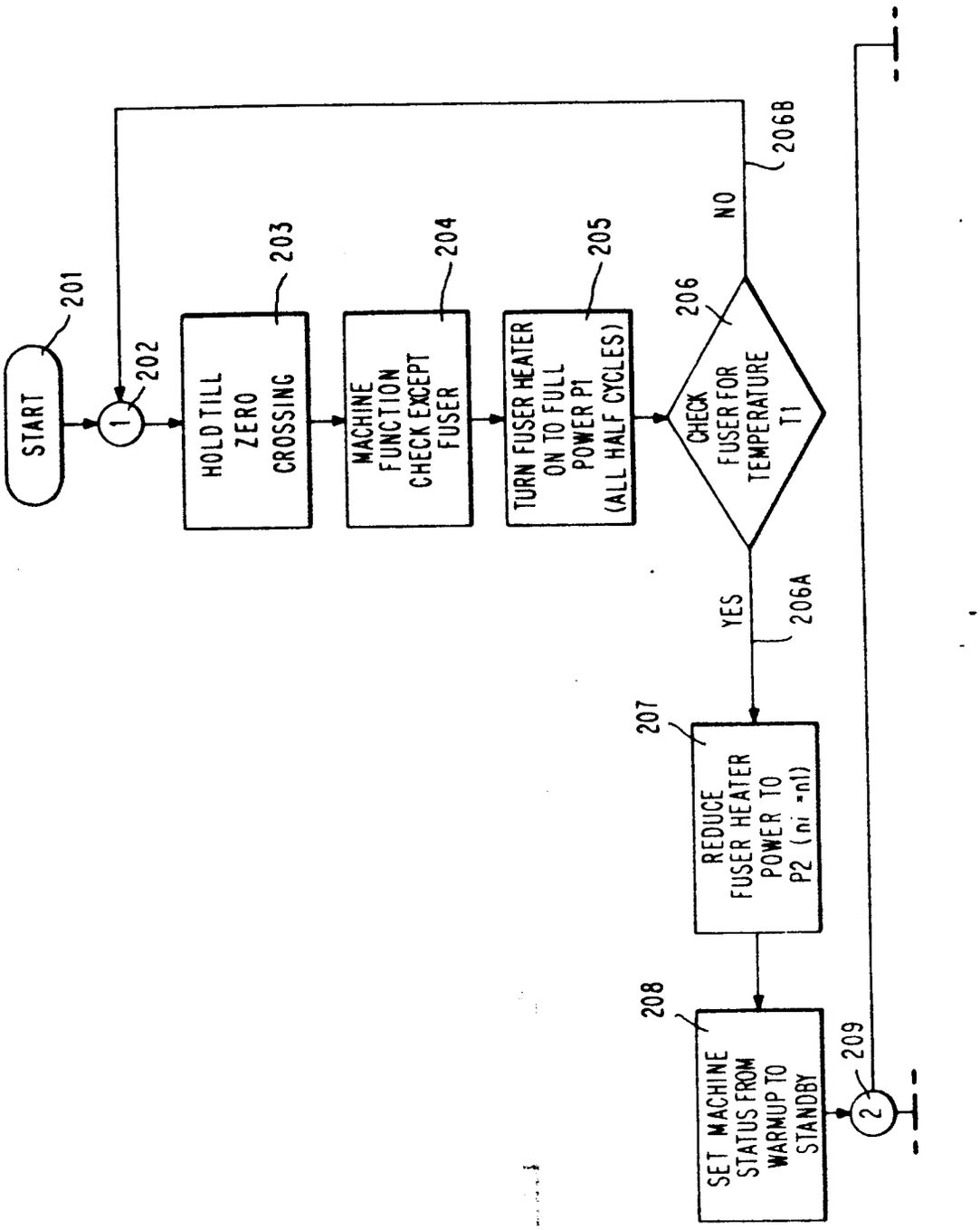

START
201
1
202
HOLD TILL ZERO CROSSING
203
MACHINE FUNCTION CHECK EXCEPT FUSER
204
TURN FUSER HEATER ON TO FULL POWER P1 (ALL HALF CYCLES)
205
CHECK FUSER FOR TEMPERATURE T1
206
NO
206B
YES
206A
REDUCE FUSER HEATER POWER TO P2 (ni -n1)
207
SET MACHINE STATUS FROM WARMUP TO STANDBY
208
2
209

FIG. 9A

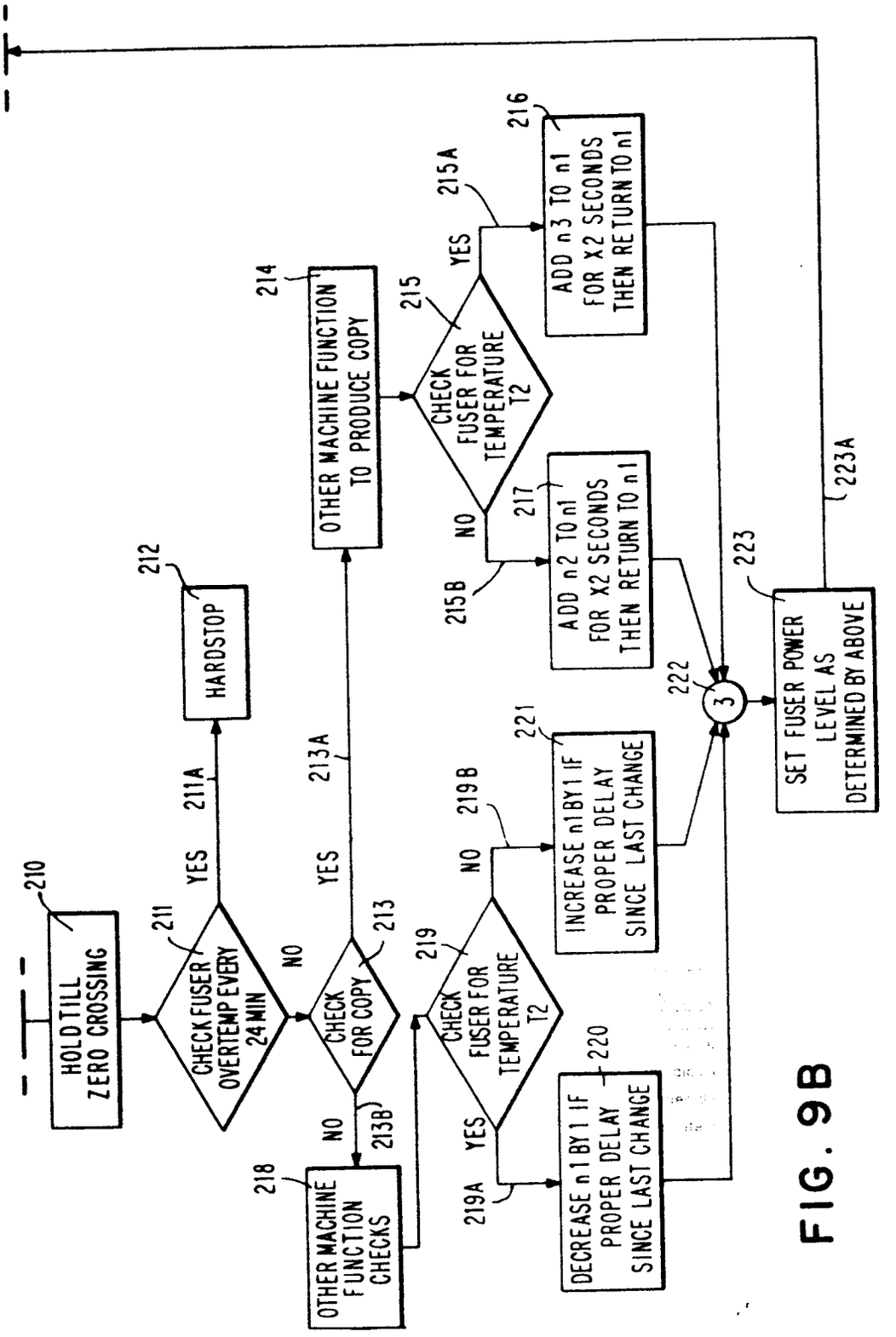

HOLD TILL ZERO CROSSING
210
CHECK FUSER OVERTEMP EVERY 24 MIN
211
YES
211A
HARDSTOP
212
NO
CHECK FOR COPY
213
YES
213A
OTHER MACHINE FUNCTION TO PRODUCE COPY
214
NO
213B
OTHER MACHINE FUNCTION CHECKS
218
CHECK FUSER FOR TEMPERATURE T2
219
NO
219B
INCREASE n1 BY 1 IF PROPER DELAY SINCE LAST CHANGE
221
YES
219A
DECREASE n1 BY 1 IF PROPER DELAY SINCE LAST CHANGE
220
CHECK FUSER FOR TEMPERATURE T2
215
YES
215A
ADD n3 TO n1 FOR X2 SECONDS THEN RETURN TO n1
216
NO
215B
ADD n2 TO n1 FOR X2 SECONDS THEN RETURN TO n1
217
3
222
SET FUSER POWER LEVEL AS DETERMINED BY ABOVE
223
223A

FIG. 9B

European Patent Office

EUROPEAN SEARCH REPORT

0006553 Application number

EP 79 101 972.2

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
	DE - A1 - 2 717 265 (CANON) * whole document * --	1
D	US - A - 3 878 358 (XEROX) * claim 1; fig. 2 * --	1
	DE - B-1 497 119 (ADDRESSOGRAPH-MULTIGRAPH) * claims * --	1
	DE - A1 - 2 720 537 (SHARP) * claims 1, 2; page 17, 2nd paragraph; page 39; page 41; page 45 last paragraph to page 49; fig. 3, position 39 * --	6
	IBM TECHNICAL DISCLOSURE BULLETIN, Vol. 21, Nr. 2, July 1978 G.J. HOWARD et al. "Copier Fuser Controls" pages 481 to 482 --	6,7 10
P	US - A - 4 144 835 (RANK XEROX) * claims 1 to 4 * --	2
D	US - A - 3 532 855 (IBM) * fig. 1 * ----	

CLASSIFICATION OF THE APPLICATION (Int. Cl.³)

G 03 G 13/20
G 03 G 15/20

TECHNICAL FIELDS SEARCHED (Int.Cl.³)

G 03 G 13/00
G 03 G 15/00
G 03 G 21/00
G 05 D 23/19
H 05 B 1/02

CATEGORY OF CITED DOCUMENTS

X: particularly relevant
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent family, corresponding document

X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Berlin	27-09-1979	HOPPE

EPO Form 1503.1 06.78