VOLTAGE SOURCE 42

CONDUCTOR 47

CONDUCTOR 46

TRANSISTOR T4

TRANSISTOR T5

THRESHOLD LEVEL FOR CHANGING STATE OF SCHMITT TRIGGER

CHARGE ON CAPACITOR C4

FIRING PULSES ON CONDUCTOR 51 & 52

SWITCH 38

TIME →
POWER REGULATING CIRCUIT FOR XEROGRAPHIC FUSING APPARATUS

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20 Claims

ABSTRACT OF THE DISCLOSURE

A circuit for regulating the power supplied to fusing apparatus employed to fuse images in a xerographic or similar copying machine is disclosed. 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 sent to control the duty cycle 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 of steady state operations. 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.

The present invention relates generally to the power regulating and copying arts. More particularly, the invention is concerned with the provision of a power regulating circuit for controlling the power supplied to fusing apparatus of a xerographic or similar copying machine. In a xerographic copying machine a heating element is usually employed to fuse the toner image to the supporting copy sheet before the copy is made available to the operator.

Xerographic copying machines have been employed to produce high quality copies of original documents in a convenient and generally economic manner. A problem encountered in the design and utilization of xerographic copying machines employing heat fusing apparatus is the relatively large amount of thermal energy and/or the extended length of time required to fuse the fixable marking material or toner to the copy sheet. 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 operating conditions, such as 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 issues can be more critical as attempts are made to provide faster xerographic copying machines which not only produce a large number of copies in a given time period, but also provide the first copy in any copying run in the shortest possible time.

It is the primary or ultimate object of this invention to provide a circuit for controlling the power supplied to heat fusing apparatus of a xerographic or similar copying machine. The power supplied to the fusing apparatus is accurately regulated so that the toner image is fused under the worst case conditions, but yet the copy is not charred or burned under the best case conditions. The worst case situation might be the fusing of the first copy produced when the copying machine has not been used for an extended period of time, the toner image is relatively light, and the ambient temperature is low.

Another object of the invention is the provision of a circuit for regulating the power supplied to heat fusing apparatus which employs a voltage feedback signal corresponding to the voltage across the heating element. This voltage feedback signal is compared with a standard signal and the difference signal maintains the power supplied to the fusing apparatus at a constant level under steady state operating conditions.

A further object of the invention is to provide a power regulating circuit for xerographic fusing apparatus wherein the power is supplied at an initial high level when the fusing apparatus is used to produce the first copy and then decreased to a steady state operating level as the ambient temperature within the fusing apparatus increases. This is considered particularly important since it permits the time required to produce the first copies to remain the same as the time needed to produce subsequent copies while insuring the first copies are adequately fused even when the copying machine has not been used to produce copies for an extended period of time and the fusing apparatus is cold. When power is applied to the regulating circuit, a capacitor begins to charge. Until it is charged to a predetermined level, the power supplies to the fusing is increased over that supplied under steady state operating conditions by an amount indirectly proportional to the charge on the capacitor.

Another object of the invention is the provision of a power regulating circuit for xerographic fusing apparatus which employs voltage feedback techniques and incorporates highly simplified means to compensate for the difference between the average and the root mean square voltage. This compensation permits the power to the fusing apparatus to be regulated such that the power is directly proportional to the root mean square voltage which is applied to the fusing apparatus.

A still further object of the invention is to provide a power regulating circuit of the type set forth above which is characterized by its high reliability and low cost. The circuit has proven capable of performing its function over a wide range of operating conditions for extended periods of time. Standard and relatively low cost circuit components are employed throughout the circuit.

The foregoing and other objects and advantages of the invention will be apparent from the following more particular description of a preferred embodiment of the invention as illustrated in the accompanying drawings.

In the drawings:

FIG. 1 is a schematic side view of a xerographic copying machine employing a power regulating circuit for the fusing apparatus constructed and operated in accordance with the teachings of the present invention;

FIG. 2 is a block diagram of the circuit for supplying power to the fusion apparatus;

FIG. 3 is a detailed circuit diagram showing particularly the detailed construction of the regulating circuit; and

FIG. 4 is a series of waveforms depicting the voltages at various points in the regulating circuit of FIG. 3.

XEROGRAPHIC COPYING MACHINE AND FUSING APPARATUS

Referring now to the drawings, and initially to FIG. 1 thereof, there is shown a schematic representation of a xerographic copying machine embodying the power regulating circuit of the present invention. The electrophotographic member of the copying machine comprises a
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3,582,855 3 drum 10 which is mounted for rotation in the direction indicated by arrow 11. Disposed on the outer periphery of the drum is a thin layer of photosensitive material 12 which is supported on a conductive substrate. The photoconductor is 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 photosensitive material 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 photosensitive material 12 as the drum rotates.

The next station in the direction of rotation of the drum 10 is a cascade developer unit 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 or toner which is attracted to and deposited on the surface of the photosensitive member 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 surface of the drum. 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 cascade 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 series of 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 a 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 25 of the copy sheets.

In operation, the heating unit 34 moves from the initial position to a final position indicated by the 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 the coincidental application of R. T. Ritchie and J. V. Cely, entitled, "Xerographic Fusing Apparatus," Ser. No. 697,734, filed Jan. 15, 1968 and which is assigned of the present invention.

The foregoing description of a representative xerographic copying machine and fusing apparatus is not intended to limit the present invention. The principles of the power regulating circuit disclosed herein can be employed in a wide variety of power regulating applications, although they find particular utility when combined to regulate the power supplied to fusing apparatus of a xerographic copying machine.

POWER SUPPLY AND REGULATING CIRCUIT

The circuit for supplying power to the heating lamp 38 is shown in FIGS. 2 and 3 of the drawings. A step down transformer 40 has its primary side connected to a source of alternating current voltage 42, such as a standard 115 volt-15 ampere-60 cycle convenience outlet found in most buildings in this country. A full wave rectifier comprising diodes D1 and D8, resistor R7 and filter capacitor C8 is connected at the output of transformer secondary 43 and provides a direct current voltage over conductor 44 to a regulating circuit generally designated by the reference numeral 45. The transformer secondary 43 also supplies two low voltage alternating current synchronizing signals over conductors 46 and 47 to the regulating circuit. The components and detailed operation of the regulating circuit 45 will be hereinafter more fully described.

The heating lamp 38 for the xerographic fusing apparatus is connected in series with thyristor 48, inductor 49 and capacitor 50 across the source of alternating current voltage 42. The thyristor 48 is a silicon bidirectional triode device or switch capable of conducting relatively high current in both directions and whose time of initial conduction during a half cycle is dependent on when the control voltage impressed between conductors 51 and 52 exceeds a threshold or firing level. Once the thyristor or switch 48 is rendered conductive during a half cycle of the supply voltage it will remain conductive until the supply voltage is reversed at the beginning of the next half cycle of the supply voltage. The inductor 49 and capacitor 50 form a low pass filter to suppress interference propagation back to the source 42. The switch 48 and the filter are preferably enclosed in a metal box to reduce radio frequency interference radiation.

The power regulating circuit 45 also receives a signal over feedback conductor 54 corresponding to the voltage across the heating lamp 38. This feedback signal is used by the power regulating circuit to control the phase angle of the firing of switch 48. The firing signals are transmitted over conductors 51 and 52. The synchronizing signals on conductors 46 and 47 reference the triggering pulses which fire the switch 48 to the line voltage. The overall arrangement is that by controlling the firing angle of the switch 48 the root mean square voltage across the heating lamp 38 is accurately regulated. In certain applications the low pass filter provided by inductor 49 and capacitor 50 can be eliminated if interfacing the control circuit is not a problem and/or the feedback signal can be taken from one of the conductors 51 and 52 rather than providing a separate feedback conductor 54.

Connected in the feedback conductor 54 are resistors R8 and R9 as is shown in FIG. 3 of the drawings. A bidirectional pulsating current flows through these resistors and is applied to transistor T1. It is noted that in the schematic circuit diagram of FIG. 3 of the drawing a
drafting convention is employed to the effect that any conductor leading to the base of a transistor is directly connected to any other conductor leading to the base of the same transistor. The current in the feedback conductor corresponds and is directly proportional to the voltage across the heating lamp 38. The transistors T₁, T₂ and T₃; resistors R₆ and R₇; and diode D₅ form a rectifying network that receives the feedback signal on conductor 54 and produces a direct current signal on conductor 55. This current produces a voltage at the base of transistors T₁ and T₂ such that a nearly equal current flows through transistors T₁ and T₂. The result of the operation of the rectifying network is a direct current signal Iₘ on conductor 55 flowing from current summing node 56 that very closely approximates the magnitude of the alternating current in the feedback conductor 54.

A steady state reference current I₀ flows to the summing node 56 and is provided by transistor T₀ and its associated circuitry. The emitter of transistor T₀ is connected in series with resistors R₆ and R₇ and by conductor 44 to the source of direct voltage for the regulating circuit. A resistor R₄ is connected between the emitter of the transistor T₀ and ground. This resistor, as will be later explained, is important in accomplishing the objects of the invention since it permits automatic compensation between the average and root mean square voltages. The base of transistor T₀ is biased by a circuit including diode D₁ and a Zener diode Z₁. The Zener diode provides a constant reference potential to the base of transistor T₀ so that it can function in its intended manner as a constant current source which is not affected by changes in the supply voltage and the like.

An important feature of the regulator circuit 45 is its ability to supply an increased level of power to the heating lamp 38 for a predetermined time period when the copying machine is first energized after standing idle for an extended period of time. This automatic control function is provided by transistor T₀ and its associated circuitry including capacitor C₁. When the copying machine is first energized under the conditions stated, transistor T₀ conducts and an initial current I₁ flows toward the summing node 56. The capacitor C₁ is initially fully discharged, but it begins to charge immediately at an exponential rate over a charging circuit provided by conductor 44 and resistor R₄. The increasing voltage across the capacitor C₁ progressively reduces the conduction of transistor T₀. Eventually the voltage on the capacitor C₁ reaches a level where the transistor T₀ is biased off and becomes nonconducting.

In a constructed embodiment of the invention, the transistor T₀ conducts for a period of about 45 seconds from the time power is applied to the regulating circuit when the capacitor C₁ is completely discharged. This time interval represents the time required to produce approximately seven copies in a multiple copy mode for a particular design of a xerographic copying machine of the general type shown in FIG. 1 of the drawings. When the heating lamp 38 is first energized, the power supplied to it is approximately 1050 watts, which is about 123 percent of the 850 watts consumed by the heating lamp under steady state operating conditions. The power supplied to the heating lamp progressively decreases from the high initial level to a steady state level in an exponential manner which is indirectly proportional to the build up of voltage across the capacitor C₁. The exponential decrease in the power offers an important advantage over a step function decrease that might be provided by switching various circuit portions in that it closely matches the exponential increase in the thermal energy stored in the fusing apparatus.

After the regulating circuit is disconnected from its power source when a fusing operation is completed, the capacitor C₁ begins to discharge through resistors R₆ and R₇. The time constant for the discharge of capacitor C₁ is relatively long and selected in accordance with the heat radiating and loss characteristics of the fusing apparatus. Thus, if a copying operation is initiated right after the fusing operation has been completed, the fusing apparatus will still be warm and the residual charge on the capacitor C₁ will limit the additional power supplied to the heating lamp 38 to a relatively low amount. The discharge rate or time constant of the discharge circuit depends on the fact that the capacitor C₁ is selected to closely approximate the cooling rate or thermal time constant of the fusing apparatus and this can be accomplished with a relatively high degree of accuracy since both are exponential functions.

The current I₀ corresponding to the feedback signal represents the actual power being consumed by the heating lamp 38 and the currents I₅ and I₆ provided by transistors T₅ and T₆ are added at the summing node 56 and integrated by capacitor C₇. This arrangement produces a voltage across C₇ which is constant only if the sum of the three currents is equal to zero. If the sum of the three currents has been rendered non-conductive and the initial current I₀ is zero, the reference current I₅ is greater than the feedback current I₀, the voltage across capacitor C₇ decreases until either the power supplied to the heating lamp 38 is adjusted and the feedback current I₅ is equal to the reference current I₅ or the reference source saturates. Conversely, if the feedback current I₅ is greater than the reference current I₅, the voltage on capacitor C₇ increases until either the currents are again equalized by regulating the power supplied to the heating lamp or the rectifying transistors T₂ and T₃ saturate.

Transistors T₁₃ and T₁₄ together form a differential amplifier current source whose output current is proportional to the difference in voltage between the reference voltage provided by Zener diode Z₄ and the voltage across capacitor C₅. The current through the resistor R₃₁ nearly constant and its division between the conducting transistors T₃ and T₄ is determined by the voltage across capacitor C₅ which is in the base circuit for the transistor T₃. The current flowing through transistor T₃ charges capacitor C₅ over a circuit comprising resistor R₃₆. The arrangement is such that the voltage across the capacitor C₅ is a linearly increasing ramp voltage whose rate of increase or slope varies in accordance with the voltage on capacitor C₅. The voltage on capacitor C₅ is, as explained above, in turn dependent on the resultant sum of the currents I₁₅, I₁₆ and I₅ at the summing node 56.

The capacitor C₅ is automatically reset or discharged to zero each half cycle of and in synchronization with the alternating current source 42. The synchronizing circuitry used to periodically discharge the capacitor C₅ comprises transistors T₄ and T₅ and their associated input networks. One of the input networks for the transistor T₄ includes a pair of diodes D₈ and D₉ connected in opposite directions or back-to-back relay in the conductor 47 and diode D₉ which establishes a bias level. The anodes of the diodes D₈ and D₉ are connected to conductor 44 via resistors R₃₈ and R₃₉. In the absence of a positive voltage signal on the conductor 47, current flows through resistor R₃₈ and forward biased diode D₈. No current is conducted to the base of transistor T₄ and it remains non-conductive. However, when the signal on conductor 47 becomes positive by an amount sufficient to counterbalance the drop across diode D₉, the diode D₉ is biased off and diode D₈ is forward biased so that base current is supplied to transistor T₄ and it immediately becomes conductive. The voltage across R₃₈ turns transistor T₄ on under these conditions and the increasing voltage drop across re-
sistor \( R_3 \) biases transistor \( T_4 \) to its non-conducting state.

The other input network is identical to the one previously described and comprises the diodes \( D_3 \) and \( D_4 \) connected in back-to-back relation in the conductor 46. The transistor \( T_4 \) will be rendered conductive during positive swings of the voltage on its gate as soon as the voltage is sufficient to overcome the bias provided by diode \( D_4 \). The voltages on the conductors 46 and 47 are 180° out of phase so that the transistor \( T_4 \) is non-conducting for a relatively short time interval at the beginning of each cycle of the supply voltage. During the periods the transistor \( T_4 \) is nonconducting, the transistor \( T_5 \) conducts and provides a discharge path for the charge on capacitor \( C_4 \). Thus, the capacitor is discharged at the beginning of each half cycle of the supply voltage. The voltage waveforms forming a portion of FIG. 4 of the drawings illustrate the operation of the transistors \( T_4 \) and \( T_5 \) with reference to the signals on conductors 46 and 47 and the supply voltage source 42.

The function of the differential amplifier provided by transistors \( T_{11} \) and \( T_{12} \) is to maintain the voltage across capacitor \( C_4 \) and the synchronizing circuitry is to produce a ramp voltage during each half cycle of the supply voltage whose slope is a linear function of and corresponds to the voltage across capacitor \( C_4 \). The slope of the ramp voltage across capacitor \( C_4 \) serves as the input to a Schmitt trigger comprising transistors \( T_7 \) and \( T_8 \). The threshold of the trigger or bistable circuit is set by the ratio of resistors \( R_{23} \) and \( R_{24} \). If it is assumed that capacitor \( C_4 \) is initially charged, transistor \( T_7 \) is not conducting while transistor \( T_8 \) is conducting. The voltage for transistor \( T_7 \) is established by the voltage divider formed by resistors \( R_{23} \) and \( R_{24} \). If a voltage drop across the resistor \( R_3 \) since transistor \( T_4 \) is conducting at this time, the Schmitt trigger will change its state when the voltage on capacitor \( C_4 \) is slightly greater than the voltage drop across resistor \( R_3 \). As previously described, the rate or slope of the voltage build up on the capacitor \( C_4 \) is varied in accordance with the regulating portions of the circuit and this results in variations in the time the trigger is actuated during successive half cycles of the supply voltage. The time of firing of the trigger during any half cycle of the supply voltage is therefore directly related to the initial, feedback and reference currents which are summed at the node 56. When the Schmitt trigger is actuated, transistor \( T_7 \) becomes conductive and transistor \( T_8 \) is turned off. The drop across resistor \( R_{23} \) is less when the trigger changes state because resistor \( R_{23} \) is much greater than resistor \( R_{24} \) and the voltage on capacitor \( C_4 \) decays slightly under these conditions. The trigger is reset when the capacitor \( C_4 \) is discharged through transistor \( T_8 \) at the time the supply voltage is reversing its polarity.

When the Schmitt trigger is actuated and the transistor \( T_7 \) is turned off, the resulting pulse through capacitor \( C_4 \) causes the transistor \( T_{13} \) to conduct. Current flows through the transistor \( T_{12} \) and resistor \( R_{26} \), and the primary of pulse transformer 59. The secondary of the pulse transformer 59 is connected via a rectifying diode \( D_4 \) to the conductors 51 and 52. Whenever the transistor \( T_4 \) conducts, a pulse is provided to the thyristor or switch 48 to fire the same. As previously indicated, once the thyristor is rendered conductive, it will continue to conduct until the polarity of the voltage is reversed at the beginning of the next half cycle of the supply voltage source.

The operation of the power regulating circuit for xerographic focusing apparatus of the present invention should now be apparent. The sum of the initial, reference and feedback currents appears at note 56 and is employed to charge capacitor \( C_2 \). The voltage on the capacitor \( C_2 \) is then applied to the controls or powers the supply to the heating lamp. After the initial current has been reduced to zero and normal operating conditions have been obtained, any variation in the feedback signal will vary the voltage on capacitor \( C_4 \) and a compensating adjustment will be made in the power supplied to the heating lamp until the reference and feedback currents are again equal.

The waveforms of FIG. 4 of the drawings are useful in understanding the operation of the synchronizing and triggering circuits which translate the voltage on capacitor \( C_4 \) to a firing voltage at the proper time during each half cycle of the supply voltage. The voltage on capacitor \( C_4 \) builds up at a linear rate as shown by curve portion 60 at a rate directly dependent upon the voltage across capacitor \( C_2 \). As soon as the voltage on capacitor \( C_4 \) exceeds the threshold or trigger level of the Schmitt trigger at point 61, the trigger changes its state and an output pulse 62 is supplied to the thyristor to render the latter conductive. The transistors \( T_5 \) becomes conductive as the supply voltage approaches zero volts and begins to change in polarity. This results in the immediate discharge of the remaining voltage on the capacitor \( C_2 \) as is represented by curve portion 63.

An important aspect of the present circuit is its ability to regulate the power input to the heating element rather than the average voltage or current. The power consumed by a load is represented by the root mean square voltage times the current for a resistive load when alternating current is employed. Over a limited range of operating conditions, the average voltage required to maintain a constant root mean square voltage is a reasonably linear function of the line voltage. A very accurate compensation for the difference between the average and root mean square voltages is provided in the present circuit by the resistance \( R_6 \) connected between the emitter of transistor \( T_{10} \) and ground. This resistor reduces the reference current \( I_0 \) supplied by transistor \( T_{19} \) at a linear rate with increasing line voltage which compensates for the increasing ratio of root mean square to average voltage at the small thyristor firing angles necessary with high line voltages. The adjustable resistor \( R_8 \) in the emitter circuit of transistors \( T_{10} \) permits setting of the circuit to compensate for tolerance variations between different circuit components. It should now be apparent that the objects initially set forth have been accomplished and that various changes can be made in the disclosed embodiment without departing from the teachings of the invention.

What is claimed is:

1. A control circuit for regulating electrical energy supplied to a heating element comprising:
   - a heating apparatus wherein the heat produced by a heating element and heat stored in said heating apparatus assists in heating a member;
   - a heating element in said heating apparatus;
   - a source of supply voltage;
   - a switch means connected between said source of supply voltage and said heating element;
   - said switch means having at least one control element and being rendered conductive when a signal supplied to said control element exceeds a predetermined threshold level;
   - means for supplying a signal to said control element;
   - means to control the rate at which signal energy is supplied to said control element;
   - said means to control comprising feedback circuit means for supplying energy in accordance with the voltage supplied to said heating element and a circuit providing a supply of energy on an exponential basis from a relatively high initial level to a relatively steady state level for a predetermined time period after said control circuit is initially energized to increase the heat generated by said heating element for a period of time corresponding to the time required to heat said heating apparatus to a predetermined temperature.

2. Apparatus according to claim 1 further characterized by:
   - said circuit providing a supply of energy comprising an energy storage device;
   - said heating apparatus storing heat at an exponential rate in a first time interval after said heating ele-
ment is initially energized and losing its heat at an exponential rate in a second time interval after said heating element has been de-energized; a charging circuit for said energy storage device having a time constant corresponding to the rate of heating of said heating apparatus; and a discharging circuit for said second energy storage device and operative when said heating element is de-energized having a time constant corresponding to the rate of cooling of said heating apparatus.

3. Apparatus according to claim 1 further characterized by:
said circuit providing a supply of energy comprising an energy storage device;
said heating apparatus storing heat at an exponential rate in a first time interval after said heating element is initially energized and losing its heat at an exponential rate in a second time interval after said heating element has been de-energized;
a first circuit for regulating the energy stored in said energy storage device having a time constant corresponding to the rate of heating of said heating apparatus; and a second circuit for regulating the energy stored in said energy storage device having a time constant corresponding to the rate of cooling of said heating apparatus.

4. Apparatus according to claim 3 further characterized by:
said feedback circuit means providing a feedback signal corresponding to the average voltage supplied to said heating element and circuit means associated with said feedback circuit means for compensating for the difference between the average voltage and the root mean square voltage supplied to said heating apparatus.

5. A control circuit for regulating the electrical energy supplied to a heating element, comprising:
heating apparatus wherein the heat produced by a heating element and the heat stored in said heating apparatus assists in heating a member; a heating element in said heating apparatus; a source of supply voltage; a switch means connected between said source of supply voltage and said heating element; a control element for said switch means and said switch means being rendered conductive when a signal supplied to said control element exceeds a predetermined threshold level; means for supplying a signal to said control element; means to control the signal supplied to said control element comprising a first energy storage device; feedback circuit means for supplying energy to said first energy storage device in accordance with variations in the voltage supplied to said heating element; said heating apparatus storing heat at an exponential rate with a thermal time constant when said heating element is initially energized and said heating apparatus is cool; circuit means comprising a second energy storage device for supplying energy to said first energy storage device in accordance with the energy stored in said second energy storage device; and means to regulate the energy in said second energy storage device at an exponential rate corresponding to the exponential rate of heat build up in said heating element when said heating element is initially energized whereby said heating element is energized at a level which is progressively decreased as the heat is stored in said heating apparatus.

6. Apparatus according to claim 5 further characterized by:
a circuit for regulating the energy stored in said second energy storage device when said heating element is de-energized;
11. Apparatus according to claim 10 wherein said circuit means for compensating comprises:
a transistor having a base terminal and two other terminals;
a source of reference voltage having first and second terminals;
said two other terminals of said transistor being connected across said first and second terminals of said source of reference voltage and defining a constant reference current source; and
a resistor connected between one of said two other terminals of said transistor and one of said first and second terminals of said source of reference voltage, said resistor serving to reduce the reference current through said transistor at a linear rate with increasing reference voltage from said reference source.

12. A control circuit for regulating the electrical energy supplied to a heating element, comprising:
heating apparatus in a copying machine wherein the heat produced by a heating element and the heat stored in said heating apparatus assists in heating a said blank;
a heating element in said heating apparatus;
as a source of supply voltage;
a switch means connected between said source of supply voltage and said heating element;
said switch means having at least one control element and being rendered conductive when a signal supplied to said control element exceeds a predetermined threshold value;
means for supplying a signal to said control element;
means to control the signal supplied to said control element comprising a feedback circuit for supplying a feedback signal corresponding to the voltage supplied to said heating element;
an energy storage device;
means to regulate the energy in said energy storage device in accordance with said feedback signal;
a ramp generating circuit for producing periodic ramp voltage signals;
means to vary the slopes of said periodic ramp voltage signals in accordance with the energy stored in said energy storage device; and
means to render said switch means conductive when said ramp voltage reaches a predetermined level.

13. Apparatus according to claim 12 further characterized by:
said source of supply voltage comprising an alternating current voltage source; and
means to synchronize said ramp generating circuit with said alternating current voltage source.

14. Apparatus according to claim 12 wherein said means to render comprises:
a bistable voltage level sensitive circuit; and
said level sensitive circuit switching its state when said ramp voltage signals exceed a threshold level; and
means to reset said bistable level sensitive circuit.

15. Apparatus according to claim 12 further characterized by:
circuit means associated with said feedback circuit for compensating for the difference between the average voltage and the root mean square voltage supplied to said heating element.

16. Apparatus according to claim 12 further characterized by:
said heating apparatus storing heat at an exponential rate in accordance with a thermal time constant when said heating element is initially energized and said heating apparatus is cool;
said means to regulate comprising a second energy storage device for supplying energy to said first energy storage device in accordance with the energy stored in said second energy storage device; and
means to regulate the energy in said second energy storage device at an exponential rate corresponding to the exponential rate of heat build up in said heating element when said heating element is initially energized whereby said heating element is energized at a high energy level which is progressively decreased as the heat is stored in said heating apparatus.

17. A control circuit for regulating the electrical energy supplied to an electrical load comprising:
an electrical load;
said source of supply voltage;
a switch means connected between said source of supply voltage and said load;
said switch means having at least one control element and being rendered conductive when a signal supplied to said control element exceeds a predetermined threshold level;
means for supplying a signal to said control element;
means to control the signal supplied to said control element comprising a feedback circuit for supplying a feedback signal corresponding to the voltage supplied to said load;
an energy storage device;
means to regulate the energy in said energy storage device in accordance with said feedback signal;
a ramp generating circuit for producing a periodic ramp voltage signals;
means to vary the slopes of said periodic ramp voltage signals in accordance with the energy stored in said energy storage device; and
means to render said switch means conductive when said ramp voltage reaches a predetermined level.

18. Apparatus according to claim 17 further characterized by:
said source of supply voltage comprising an alternating current voltage source; and
means to synchronize said ramp generating circuit with said alternating current voltage source.

19. Apparatus according to claim 17 wherein said means to render comprises:
a bistable voltage level sensitive circuit; and
said level sensitive circuit switching its state when said ramp voltage signals exceed a threshold level; and
means to reset said bistable level sensitive circuit.

20. Apparatus according to claim 17 further characterized by:
circuit means associated with said feedback circuit for compensating for the difference between the average voltage and the root mean square voltage supplied to said heating element.

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In the drawings, Sheet 2, FIG. 3, a circuit connection should be made by way of a line from the base of transistor T12 (center section) for approximately one-half inch to the right for connection with the line between diode D3 and the collector of transistor T6. Further, the vertical line connecting diode D9 and the emitter of transistor T3 to ground should be removed.