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A. R. KOTZ ET AL

3,056,904

THERMOPRINTING APPARATUS AND METHOD

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2 Sheets-Sheet 1

FIG. 1

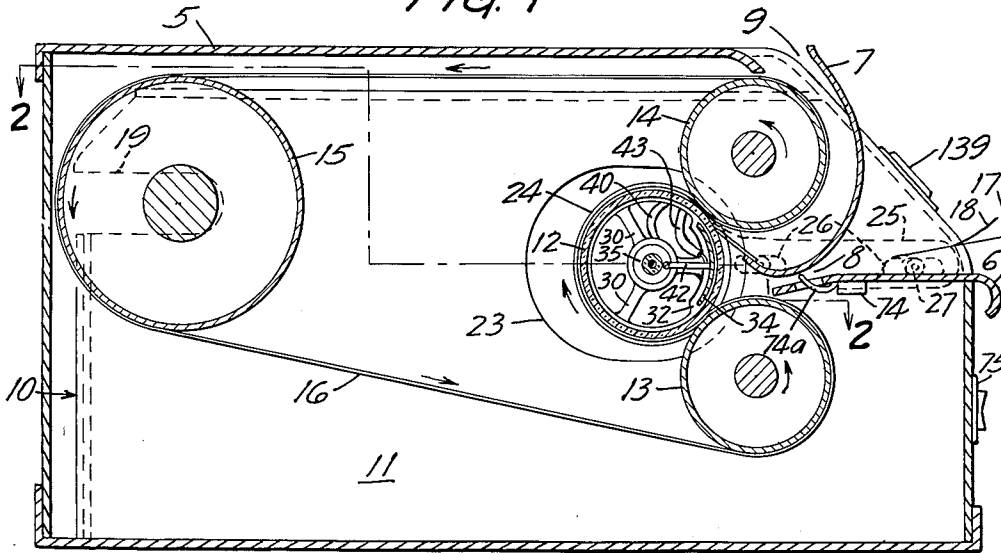
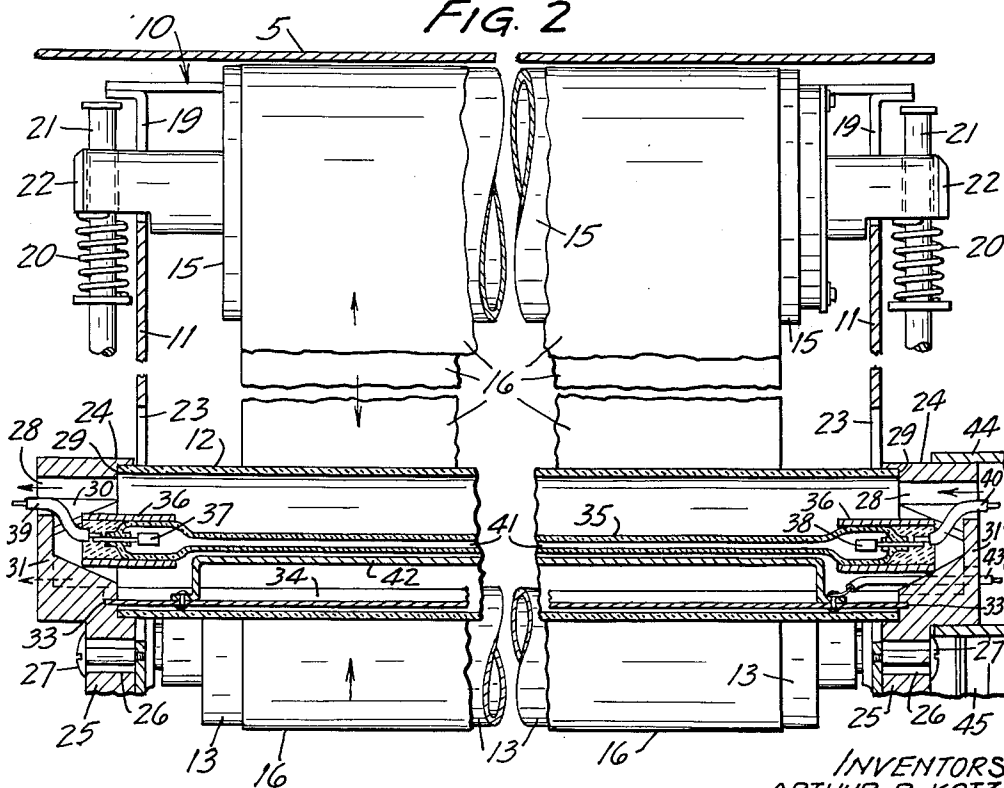


FIG. 2



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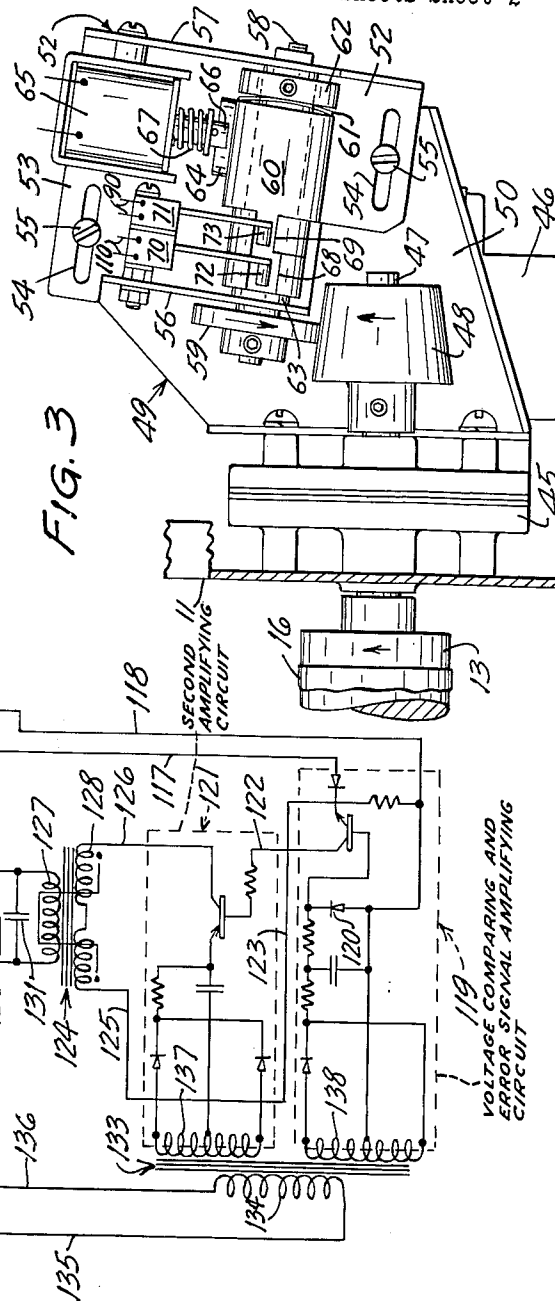
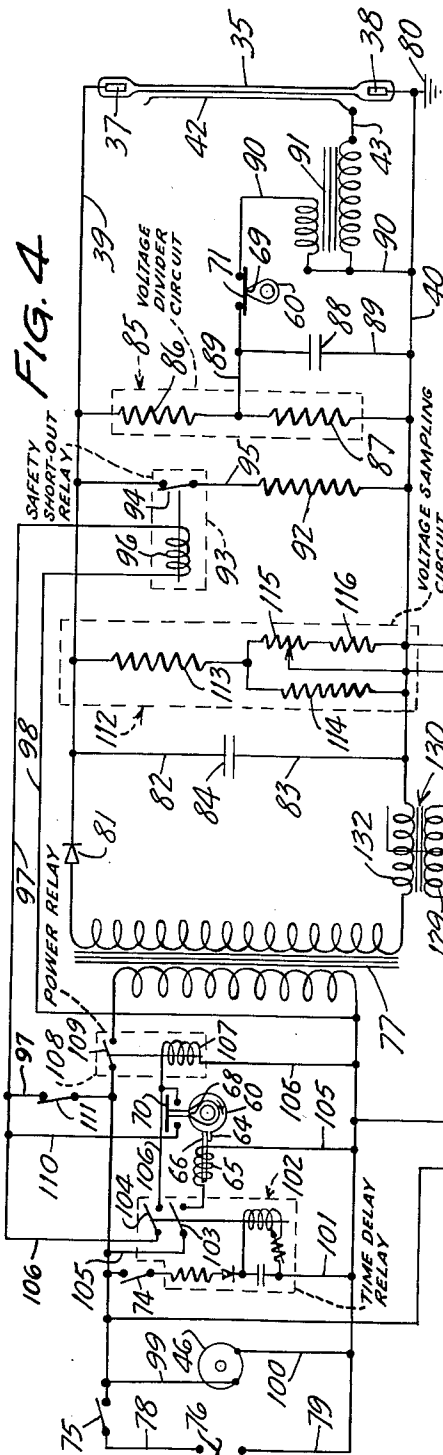
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THERMOPRINTING APPARATUS AND METHOD
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This invention relates to the reproduction of graphic originals by heat-printing, and has particular reference to economical apparatus capable of rapidly producing any required number of reproductions of printed or hand-written matter, sketches, drawings, photographic prints, and many other types of graphic originals, on heat-sensitive copy-paper. There is involved the conversion of radiant energy to heat energy at the graphic representation, and the utilization of the resulting heat-pattern in providing a corresponding visible pattern in the copy-paper. Graphic representations made with colored inks or pencils as well as with carbon inks or pencils are successfully copied, and accordingly the invention has been found particularly applicable to the copying of documents carrying signatures as well as those printed in multiple colors.

Typical heat-sensitive copy-papers which, along with other types, may effectively be used with the apparatus of this invention are disclosed in Clark U.S. Patent No. 2,813,043 and others therein cited. Such papers have been used with apparatus described in Miller U.S. Patent No. 2,740,895 and by methods described in Miller U.S. Patent No. 2,740,896, in which intense radiation from electrically heated tungsten filaments provided the required heat-pattern for visible reproduction. They have also been used with apparatus and by methods of Miller et al. U.S. Patent No. 2,844,733 employing a high potential discharge in an ionized gas as the source of radiation.

The present invention likewise calls for a gas flash source of radiation but, unlike the method of the Miller et al. patent, produces a direct rather than an inverse reproduction of the printed characters, signature, or other graphic representation. Thus a signature in blue or red ink on white paper will be copied, for example, as a black signature on a white or buff background rather than as a white or buff signature on a black background. The apparatus employed is capable of reproducing originals of any length, utilizing a single flash lamp of novel construction for instantaneous flash type irradiation of successive contiguous areas of a composite graphic original and copy sheet in timed relation to the advancement of the composite past the lamp. The novel lamp construction not only provides a radiation pulse having an increased percentage of the shorter wavelength light rays facilitating reproduction of difficult-to-copy colors, but it also permits substantial reductions in the cost of the machine as well. The mechanism as well as the electrical circuitry of the machine incorporates a number of novel features insuring the production of uniform copies of the most diverse types of graphic originals and irrespective of line voltage variation. The machine is efficient, safe and easily operated, and is otherwise well adapted for the purposes described.

These and other advantageous qualifications are obtained, in accordance with the present invention, by means of the apparatus which will now be described in connection with the accompanying drawings, in which:

FIGURE 1 is a vertical sectional view taken from front to back through the copying area of a typical copying machine constructed in accordance with the invention;

FIGURE 2 is a fragmentary sectional plan view of a

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portion of the machine of FIGURE 1 taken along the line II—II of FIGURE 1;

FIGURE 3 is a fragmentary plan view of another portion of the machine of FIGURE 1 showing the timing mechanism, together with the drive means for the conveyor web and for said mechanism; and

FIGURE 4 schematically represents the electrical circuitry of the improved machine.

Referring now to FIGURES 1 and 2, the improved thermocopying machine is provided with a casing 5 including a ledge member 6 and a curved guide member 7 defining an inlet channel 8 and an outlet channel 9. Within the housing 5 is a supporting frame 10 having parallel side members 11. Mounted on the frame 10 for rotation on parallel axes in the spacial relationship shown, are a copy roll 12, a feed roll 13, a discharge roll 14 and a tensioning idler roll 15. Traversing the rolls 12 through 15 as best shown in FIGURE 1 is a flexible endless web or belt 16 of substantial width. A composite of a graphic original 17 and heat-sensitive copy paper 18 inserted into the entrance channel 8 is conveyed by the web 16 around the copy roll 12 and out of the discharge channel 9.

The feed roll 13 and discharge roll 14 may be mounted in suitable fixed bearings, whereas the copy roll mounting to be described hereinafter, is of the floating type. The tensioning roller 15 may be bearinged on a shaft 22 supported in slots 19 in the frame members 11 and biased rearwardly by springs 20 carried by rods 21 extending loosely through diametrical bores in the shaft 22. The rods 21 are suitably anchored to the frame members 11, and the bias of the springs 20 exerts a strong tension upon the web 16 such that said web exerts a heavy compressive stress on all portions of the composite disposed between said web and the copy roll 12 during the passage of the composite through the machine.

The copy roll 12 takes the form of a cylindrical sleeve of glass or other suitable material, the end portions of which extend through apertures 23 in frame members 11 and are received in bearing guide members 24 which may be of any suitable electrical insulating material, for example, the plastic material known commercially as nylon. The bearing members 24 are each formed with extended arm portions 25 which are formed with horizontal slots 26 for slidably receiving mounting screws 27 threaded into the frame members 11 as shown in FIGURE 2. The cooperation of the mounting screws 27 with the slots 26 permits free floating movement of the bearing guides 24, and hence of copy roll 12, in the plane normal to the axis of said copy roll.

Bearing guides 24 are each formed with a bore 28 and with a counterbore 29 in which the adjacent open end of the copy roll 12 is rotatably received. The bearing guides 24 are also formed with a plurality of generally triangular web portions 30 joined at a central hub 31, and each is also formed with an arcuate boss 32 shown most clearly in FIGURE 1. The bosses 32 are each formed with an arcuate slot 33 for receiving and supporting the adjacent end of an elongated metallic shield-reflector 34, of arcuate cross-section, the inner surface of which is preferably coated with a layer of light-reflective ceramic.

An elongated gas flash lamp 35 having a tubular cylindrical main body portion and bulbar end portions is provided at said end portions with tubular insulating mounting members 36 which engage the web portions 30 of the bearings 24 as shown most clearly in FIGURE 2, to provide a support for the lamp 35 maintaining the main body portion thereof coaxial with the copy roll 12. Electrodes 37 and 38 which are respectively anode and cathode, are disposed within the opposite bulbar end portions of the lamp 35, as shown, and are provided with terminal

portions extending outwardly of the lamp envelope for attachment to electrical connections 39 and 40 respectively. The lamp envelope is hermetically sealed and defines an arc chamber which contains an ionizable fluid, preferably a noble gaseous fill such as commercially available xenon gas, as a fill. The main body portion of the lamp 35 preferably has a bore 41 the size of which is of the order of a capillary, i.e., not substantially larger than two millimeters in diameter, and the xenon gas is preferably under a pressure of from 500 to 760 millimeters of mercury.

Electrically connected to and mounted on the shield-reflector 34 is a generally U-shaped trigger electrode 42 having an elongated straight line main body portion extending parallel with the main body portion of the flash lamp 35 and adjacent the periphery thereof as shown. A suitable electrical connection member 43 is connected in circuit with the trigger electrode 42, either directly as shown, or by connection to the shield-reflector 34, said connection member, like connection members 39 and 40, extending outwardly through the adjacent bearing guide 24 between the web portions 30 thereof as shown. Where the connection member 43 is connected directly to the trigger electrode 42, said electrode need not be electrically connected to the shield-reflector 34. To prevent overheating of the copy roll 12, a conduit 44 leading from the outlet of a blower (not shown) is telescoped over one of the bearing guides 24 and supplies cooling air which flows longitudinally through the annular space between the flash lamp 35 and copy roll 12 and out the other bearing guide 24.

It will be observed that in addition to affording a support for the trigger electrode 42, the shield-reflector 34 shields a portion of the inner surface of the copy roll 12 from the radiations of the lamp 35 to hereby define on the side wall of said copy roll, and between the upper and lower edges of the shield-reflector 34, an exposure area of predetermined circumferential length through which a composite can be irradiated by the flash lamp. In addition, of course, the shield-reflector also functions to reflect toward the aforementioned exposure area radiations impinging thereagainst.

The tension exerted on the web 16 by the springs 20 through the tensioning roll 15 causes the copy roll 12 to be constricted within the bight portion of the web extending around the copy roll from the feed roll 13 to the discharge roll 14. This constriction not only affords the heavy compressive pressure on the composite aforementioned, but it also causes the web 16 to afford substantially all of the support for the copy roll 12. The bearing guides 24 are normally operative to limit axial movement of the copy roll 12 and actually support said copy roll only when the tension on the web 16 is relieved, for example on removal of the web from the machine. It is apparent, however, that the bearing guides 24 do afford means for retaining the copy roll 12, flash lamp 35, shield reflector 34 and trigger electrode 42 as a unitary assemblage in which the spacial relationships of the components of said assemblage are maintained even though said assemblage can move as a unit within the limits permitted by the aforementioned floating mounting.

Movement of the web 16 in the direction indicated by the arrows is provided by drive mechanism under the control of a normally open start switch 74 having an actuating arm 74a positioned within the throat of the entrance channel 8 and actuatable by insertion of a composite into the machine. The illustrated drive mechanism is associated with the feed roll 13 and is shown most clearly in FIGURE 3 to which reference is now made.

A gear reduction unit 45 is mounted on one of the frame members 11 and is drivingly interposed between one end of the shaft of the feed roll 13 and a drive motor 46. Also extending from the gear reduction unit 45 and driven therefrom by the motor 46 is a shaft 47 to which a driving cone 48 is coaxially fixed. Fixed to the reduc-

tion unit 45 above the motor 46 is a mounting bracket 49 having a horizontal platform portion 50. An adjustable timing mechanism 51 is mounted on the bracket 49 and comprises a generally U-shaped bracket 52 having a platform portion 53 overlaying the platform portion 50 of the bracket 49 and slotted as at 54 to receive screws 55 threaded into the bracket 49 and adjustably securing the bracket 52 thereto. The bracket 52 is formed with upstanding flanges 56 and 57 affording a rotatable support for a cam shaft 58 which carries at one end a wheel 59 having a periphery of frictional material engaging the driving cone 48. A cam sleeve 60 is disposed coaxially on the cam shaft 58 and has sliding frictional engagement therewith. The desired frictional engagement may be attained by proper selection of the material and of the bore of the cam sleeve 60 with respect to the cam shaft 58 therewithin. It is preferable, however, to insure the proper frictional engagement by adjustable means, for example by the use of a spring member, such as a thrust washer 61 interposed between the cam sleeve 60 and a collar 62 adjustably fixed on the shaft 58. The washer 61 biases the cam sleeve 60 axially against an annular shoulder 63 formed on the cam shaft 58.

The cam sleeve 60 is provided with a shoulder 64 projecting radially from the periphery thereof as shown, and a solenoid 65 is mounted on the flange 57 and has a plunger 66 biased toward the periphery of the cam sleeve 60 by a compression spring 67. When the plunger 66 is in the deenergized position shown, it is in the path of the shoulder 64 and prevents rotation of the cam sleeve 60 beyond the position shown, even though the cam shaft 58 may be rotating therewithin. Energization of the solenoid 65 effects retraction of the plunger 66 to a position clear of the shoulder 64 permitting rotation of the cam sleeve 60 with the cam shaft 58.

The cam sleeve 60 is also formed with surface irregularities or shoulder portions 68 and 69 which may be formed as in the illustrated embodiment by cutting away peripheral portions of the cam sleeve 60 so that the portions 68 and 69 are in effect radial projections with respect to the cutaway portions without extending radially beyond the periphery of the remainder of the cam sleeve 60. Mounted on the flange 56 of the bracket 52 are a biased closed micro switch 70 and a biased open micro switch 71 provided with actuating arms carrying cam following rollers 72 and 73 respectively. As will appear hereinafter, the switch 70 is a turn-off synchronization switch and the switch 71 is a trigger switch, it being apparent from FIGURE 3 that upon rotation of the cam sleeve 60 in the direction indicated, the switch 70 will be actuated momentarily before the switch 71, and that both of said switches are in the actuated position when the cam sleeve 60 is locked in the position shown by the solenoid plunger 66.

Referring now to FIGURE 4, the electrical circuitry of the embodiment of the invention selected for illustration derives its power from an alternating current source 76 which is connected in circuit with the primary winding of a power transformer 77 by means of main primary conductors 78 and 79. All of the power to the machine is under the control of a master on-off manual switch 75 which is interposed in the conductor 78 and, as shown in FIGURE 1, is mounted on the front of the casing 5. The secondary winding of the power transformer 77 is connected in parallel circuit relation with the flash lamp 35, more specifically the anode 37 and cathode 38 thereof, by means of the conductors 39 and 40 respectively, the cathode 38 being grounded as at 80. A half-wave rectifier 81 is interposed in the conductor 39 so that the current flow available from the secondary winding of the power transformer 77 to the conductors 39 and 40 is in the form of unidirectional spaced pulses for a reason which will hereinafter appear. Connected across the conductors 39 and 40, as by conductors 82 and 83 is a storage capacitor 84 which is subjected to substantially

the full voltage available from power transformer 77. The transformer 77, rectifier 81 and conductors 39, 82, 83 and 40 thus provide a charging circuit for the storage capacitor 84.

Triggering means is provided for effecting discharge through the lamp 35 of the electrical energy stored in the storage capacitor 84 by the charging circuit, said means comprising a voltage divider network 85 connected across the conductors 39 and 40 and comprising resistors 86 and 87. The voltage divider 85 supplies a reduced voltage for storage in a trigger capacitor 88 interposed in a conductor 89 connected at one end intermediate the resistors 86 and 87 and at its other end to the conductor 40 as shown. The trigger switch 71 is interposed in a conductor 90 along with the primary winding of a step-up trigger transformer 91, one end of the conductor 90 is connected to the conductor 89 between the capacitor 88 and the voltage divider 85 as shown, and the other end of the conductor 90 being connected to the conductor 40 as shown. One end of the high voltage secondary winding of the trigger transformer 91 is also connected to the conductor 90, and the other end of said secondary winding is connected in circuit with the trigger electrode 42 by the conductor 43.

While in the shut-down condition of the machine shown in FIGURE 4 the trigger switch 71 may be held closed by the cam 69, in normal operation such closure is only momentary. Thus, switch 71 is open most of the time. When the main switch 75 is closed and trigger switch 71 is opened, an electrical charge is stored in both the storage capacitor 84 and the trigger capacitor 88. Upon momentary closure of the trigger switch 71 by the cam 69 the charge stored in the trigger capacitor 88 discharges through the primary winding of the trigger transformer 91 causing a high voltage charge to be impressed across the trigger electrode 42 and the grounded cathode 38. This ionizes the gas in the lamp 35, lowering the impedance to current flow through said gas between the anode and cathode sufficiently to permit the electrical energy stored in the storage capacitor 84 to be discharged through the lamp, creating thereby a flash or radiation pulse. As soon as the energy stored in the capacitor 84 is discharged, the charging circuit substantially immediately begins recharging said capacitor. Subsequent reopening of the trigger switch 71 permits recharging of the trigger capacitor 88.

Means is provided for effecting discharge of the electrical energy that may be stored in the storage capacitor 84 in the event of a power failure, said means taking the form of a safety short-out relay 93 having biased closed contacts 94 interposed in a conductor 95 which also has a resistor 92 interposed therein, said conductor having its opposite ends connected to the conductors 39 and 40 as shown. The relay 93 has a winding 96 connected in circuit with the primary conductors 78 and 79 by conductors 97 and 98 respectively. The relay 93 is normally energized to open contacts 94 whenever the main on-off switch 75 is closed. In the event of a failure of the power source 76 or opening of the main switch 75, the relay winding 96 is deenergized to close contacts 94 and permit dissipation of any charge stored in the capacitor 84 through the resistor 92.

Closure of the main switch 75 has the immediate effect, so far as the structure thus far described is concerned, only of energizing the safety short-out relay 93 and the drive motor 46 which is connected to conductors 78 and 79 by conductors 99 and 100 as shown. Current flow to the power transformer 77 and to the solenoid 65 of the timing mechanism 51, in addition to being under the control of the main switch 75, is also under the control of the start switch 74. The switch 74 is interposed in a conductor 101 which is connected across the conductors 78 and 79 as shown and also has interposed therein the operator of a time delay relay 102. The time delay relay 102 has biased open contacts 103 and 104 compris-

ing a double pole single throw switch. The contacts 103, together with the winding of the solenoid 65, are interposed in a conductor 105 connected across the conductors 78 and 79 as shown. The contacts 104, together with the winding 107 of a power relay 108, are interposed in a conductor 106 connecting the conductors 97 and 79 as shown. The relay 108 has biased open contacts 109 interposed in the main primary conductor 78 as shown. The turn-off synchronization switch 70 is interposed in a conductor 110 which connects said switch in parallel circuit relation with the contacts 104 of relay 102 as shown.

The conductor 97 may also have one or more biased open interlock switches interposed therein as indicated at 111, said switches being positioned to be held closed by the cover or other portions of the machine when said cover or other portions are in place, said switches moving to open position by opening or removal of said cover or other portions of the housing 5. Opening of the contacts of switch or switches 111 deenergizes both the power relay 108 and the safety short-out relay 93 to thereby shut off all power to the charging circuit and to also rapidly discharge the storage capacitor 84 through the resistance 92.

To place the machine into operation, the main switch 75 is manually closed to thereby initiate operation of the drive motor 46 and hence of the web 16, and to also energize the safety short-out relay 93 to open the contacts thereof. Referring to FIGURE 3, operation of the motor 46 causes rotation of the driving cone 48, which in turn causes rotation of the driven wheel 59 by frictional engagement therewith. This causes rotation of the cam shaft 58, but the cam 60 is prevented from rotating with the cam shaft 58 since the solenoid plunger 66 is disposed in the path of the cam shoulder 64.

Entry of a composite or original and copy paper into the throat of the entrance channel 8 causes actuation of the start switch 74 and immediate closure of the contacts 103 and 104 of time delay relay 102. Closure of contacts 103 effects energization of the solenoid 65 and withdrawal of the plunger 66 to a position clear of the cam shoulder 64, permitting rotation of cam 60 with the cam shaft 58. Rotation of cam 60 moves cam portions 68 and 69 out of engagement with the cam following rollers 72 and 73 to permit closure of the switch 70 and opening of the switch 71. Closure of contacts 104 effects energization of the power relay 108 for closure of the contacts 109 thereof and energization of the power transformer 77. The secondary of the power transformer 77 supplies high voltage alternating current which is rectified by the rectifier 81 and supplied to the charging circuit in the form of spaced unidirectional pulses which store electrical energy in the storage capacitor 84 and trigger capacitor 88. In the meantime the composite of graphic original and copy paper advances in heavy pressure contact over its entire area between the web 16 and the copy roll 12. This pressure contact, by virtue of the novel arrangement whereby the copy roll 12 is supported by the web 16, is substantially greater than the pressure contact impressed upon composites by prior machines.

Substantially simultaneously with the arrival of the leading edge of the composite in radial alignment with the upper edge of the shield-reflector 34, the trigger switch 71 is actuated to closed position by the cam 69 to discharge the storage capacitor 84 through the lamp 35 and produces an intense radiation pulse which causes a direct reproduction of the graphic representations of the graphic original to appear in the heat-sensitive copy paper 18 over the area thereof in contact with the copy roll 12 and not shielded by the shield-reflector 34. As the original and copy leave the copy roll 12, they are directed out the outlet channel 9 by the guide member 7 to the top of the casing 5 where the copy is in position for immediate visual inspection.

With sufficiently short sections of original and copy

paper, a complete reproduction may be obtained with a single radiation pulse; and the apparatus is entirely satisfactory for this class of copy. It is equally effective, however, in the continuous copying of originals of extended length, and it is particularly useful for copying from conventional office or legal size originals, by irradiation of successive longitudinally contiguous areas thereof with multiple exposures.

As the composite continues to enter the machine and to depress the start switch arm 74a, the capacitors 84 and 88 are successively recharged and discharged through the lamp 35 in the manner described under the control of the cam portion 69 and trigger switch 71 as successive increments of the composite reach the edge of the exposure area defined by the upper edge of the shield-reflector 34. Exact control of the interval between radiation pulses for synchronization of the radiation pulse with the arrival of each successive increment at the upper edge of the shield-reflector 34 is achieved by adjustment of the speed of rotation of the cam 60 with respect to that of the web 16. This is accomplished by adjustment of the position of the timing mechanism 51 on bracket 49 to thereby adjust the position of the driven wheel 59 along the surface of the driving cone 48 as permitted by the screws 55 and slots 54. The accuracy obtainable, together with the sharpness of the image formed at the edges of the shield-reflector 34, is such that substantially no visible discontinuity is observed between contiguous exposure areas of the copy.

Passage of the trailing edge of the composite of graphic original and copy paper into the machine and out of engagement with the start switch arm 74a causes opening of start switch 74, and after a predetermined time delay the contacts 103 and 104 of the relay 102 open. Opening of the contacts 104 has no effect on energization of the power relay 106, since the circuit thereto is at this time completed through the turn-off synchronization switch 70. Opening of the contacts 103, however, deenergizes solenoid 65 to permit plunger 66 to move into the path of the cam shoulder 64. The cam 60 continues to rotate with the advancement of the composite through the machine, and just before the leading edge of the terminal increment of the composite reaches the upper edge of the shield-reflector 34, the cam portion 68 opens turn-off synchronization switch 70 to deenergize the power relay 103 and thereby the power transformer 77. Momentarily thereafter, simultaneously with arrival of the leading edge of the terminal increment of the composite at the upper edge of the shield-reflector 34, the cam portion 69 closes the trigger switch 71 to provide a radiation pulse for exposure of said terminal increment. As substantially the same time the shoulder 64 of cam 60 moves into engagement with the plunger 66 to stop further movement of said cam so that the switches 70 and 71 are held in the positions shown until another composite is inserted into the machine. Shutting off of the power supply to the charging circuit momentarily before triggering, i.e. at a time when the charging current is minimal, insures that after discharge the residual energy in the capacitor is minimal. Low residual energy in the capacitor after discharge lengthens capacitor life, whereas shut-off of the charging circuit at a time when the charging current is minimal reduces back electromotive forces generated in the power transformer and tending to cause destructive arcing.

Since the power transformer 77 is deenergized by opening of the power relay contacts 109, the capacitors 84 and 88 remain discharged until another composite is inserted into the machine. The delay afforded by the time delay 102 is sufficient to permit irradiation of the terminal increment of the composite regardless of the length thereof or of the distance between the start switch arm 75 and copy roll 12. In some instances the final radiation pulse may occur while the end portion of the composite surrounds most or substantially all of the exposure area of the copy roll. In another case the final radiation pulse

may take place after all of the composite has passed the exposure area. In all cases, however, the operational cycle is completed with the capacitors 84 and 88 substantially fully discharged.

The permissible speed of rotation of the copy roll 12 is dependent upon the rate of voltage build up in the capacitors 84 and 88. The charging rate is dependent upon the capacity of the capacitor, which in turn is related to the energy expended in a radiation pulse of the lamp 35, and hence to the diameter of the copy roll 12 and the exposure area per flash. We have found that for the expenditure of a given amount of electrical energy in a radiation pulse, satisfactory copying requires that the characteristics, i.e. the shape, of the radiation pulse be controlled within rather close limits. Too high a peak intensity causes destruction of the original, whereas too long a pulse duration causes low resolution, poor color pickup and low efficiency of the copying process. As will become apparent hereinafter the improved machine is provided with means for shaping the radiation pulse to afford maximum resolution, color pickup and efficiency without any deleterious effect on the original.

While wide variation is possible, it is found that a fully adequate rate of reproduction of business correspondence and analogous graphic originals is obtained when employing a flash lamp 35 having an arc length of 10 inches and a bore of 2 millimeters mounted within a copy roll 12 1 1/8 inches in diameter and powered from a 100 mfd. capacitor 84 having impressed thereon a voltage adjustable by adjustment of the knob 139 and potentiometer 115 to from 2200 to 3300 volts, with a 1 mfd. capacitor 88 supplying the triggering charge. One form of the machine utilizing a flash lamp, copy roll, power transformer and capacitors sized as specified, and having the circuitry previously described, produces a radiation pulse at approximately 1.5 second intervals and can expose an 8 1/2 x 11" original in approximately 5 seconds.

As mentioned hereinbefore, the flash lamp 35 is characterized by the main body portion having a bore of substantially capillary size, i.e. of the order of 2 millimeters. This novel type of lamp construction produces several unexpected and very desirable results. First, the reduced diameter bore affords the lamp increased efficiency, i.e. greater usable light output for a given energy input. Further, the reduced diameter bore produces, for a given peak current flow through the lamp, a radiation pulse which is substantially richer in the shorter wave length rays, more specifically blue rays, than the radiation pulse produced by the same peak current flow through a flash lamp having a larger diameter bore. Since the difficult-to-copy colors are usually blue absorbers, the radiation pulse rich in blue rays produced by the improved lamp 35 contributes substantially to the ability of the improved machine to reproduce difficult-to-copy colors. It is thought that the radiation pulse rich in the blue rays is caused by a higher current density occurring within the restricted bore for a given peak current flow. To produce in a lamp having a larger bore a current density sufficient to generate a radiation pulse correspondingly rich in blue rays would require an extremely high peak current flow through the lamp. Such extreme current flow would generate excessive heat deleteriously affecting both the composite and the conveyor web 16.

Still another advantage of the use of the restricted bore lamp 35 results from the fact that a reduction in the bore of a flash lamp effectively lengthens the duration of the radiation pulse and reduces the peak intensity of the current flow through the lamp. This is thought to be the result of impedance to current flow presented by restriction of the bore. The pulse lengthening effect of the reduced bore is the same effect as would be produced in a larger bore lamp by increasing the capacitance of the storage capacitor 84. Thus, for a given desired length of radiation pulse, the use of the lamp 35 having a restricted bore permits the use of a storage capacitor 84 having substantially less capacity than would be required

of said capacitor to produce the same length of pulse in a flash lamp having a larger bore. This feature is particularly desirable, since large capacitance capacitors are relatively large, heavy and expensive, and the bulk, weight and cost of such capacitors varies substantially directly with the capacitance thereof. Thus, the use of the restricted bore flash lamp 35 cuts down very substantially on the cost, as well as on the size and weight of the machine.

The electrical energy expended in a radiation pulse is represented by the formula $E = \frac{1}{2} CV^2$, wherein E represents the electrical energy expended in watt seconds or joules, C represents the capacitance of the storage capacitor 84 in farads, and V represents the voltage stored in the storage capacitor in volts. For a given value of electrical energy expended, and a given peak intensity a reduction in the capacitance of the capacitor 84 made possible by the improved flash lamp requires that the voltage impressed upon said capacitor be increased. This increase in voltage can be readily supplied by a change in the design of the power transformer 77, however, without any substantial increase in the bulk, weight or cost of the machine.

Conversely the restricted bore lamp affords a circuit element for controlling the shape of a current pulse therethrough. The shape of the arc chamber within the lamp is determinative of the impedance to current flow through the lamp and thus is determinative of the shape of the current pulse. Control of the shape of a current pulse by such a circuit element is possible by the selection of a lamp arc chamber shape of the character which produces the desired shape of pulse. The control of pulse shape thus provided is preferable to the control of pulse shape by external circuit means, for example by the use of a different capacitor or the use of inductors or resistors with the capacitor.

A further novel feature of the improved flash lamp 35 resides in the use of a xenon gas fill under substantially greater pressure than has been used heretofore in flash lamps, for example a pressure of 500 to 760 mm. of mercury as compared with a pressure of 300 mm. of mercury used in conventional flash lamps. Several unexpected and desirable advantages flow from the use of the higher pressure fill. More specifically the increased fill pressure affords, like the restricted bore of the lamp, substantially increased efficiency, i.e. greater usable light output for a given value of energy expended in a radiation pulse. The higher pressure fill, like the reduced diameter bore, also tends to increase the amount of shorter wave length blue rays in the radiation pulse. In addition, the higher pressure fill raises the stand-off potential of the lamp 35, i.e. it raises the level of the minimum voltage at which the storage capacitor can spontaneously discharge through the lamp, thereby permitting a higher voltage to be stored in the storage capacitor without spontaneous discharge through the lamp. Another novel feature of the machine facilitating servicing and contributing to the efficiency of the machine is the structure and mounting of the trigger electrode 42. Mounting of the trigger electrode 42 on the shield-reflector 34 permits removal and replacement of the lamp 35 without removal of the trigger electrode. It will also be observed that the trigger electrode, being disposed on the side of the lamp 35 facing the shield-reflector 34 does not in any way obstruct the travel of light rays from the lamp bore to the exposure area of the copy roll 12. Experience has shown that after prolonged operation, a deposit forms on the outer surface of flash lamps adjacent the trigger electrode. With the improved trigger electrode structure, any deposit formed would likewise not in any way obstruct the travel of the light rays from the lamp bore to the exposure area of the copy roll. For these reasons the improved trigger electrode structure is substantially more efficient than a trigger electrode of conventional form helically wound about its associated flash lamp.

Reproduction of the graphic originals by the multiple flash means afforded by the improved machine can be effective in producing fully satisfactory copies only if the contiguous exposure areas are so carefully joined and so uniformly exposed as to provide practically no distinguishable inter-edges or density variations. Inter-edges are eliminated through adjustment of the timing mechanism 51 as aforescribed, and variation in density is avoided by insuring strict uniformity of the peak intensity of the radiation pulse. It has been found, for example, that variations of more than $\pm 2\%$ in the voltage impressed upon the capacitor 84 produce observable and undesirable variations in density and copying ability. The present invention provides means for maintaining the voltage stored in the capacitor 84 well within this limit of variation in spite of any substantial variations in the voltage supplied by the source 76.

In the illustrated embodiment of the invention, the aforementioned voltage control means includes a voltage sampling circuit 112 connected across the conductors 39 and 40 as shown and including resistors 113 and 114, potentiometer 115 and variable resistor 116. The voltage sampling circuit 112 samples the voltage supplied to the storage capacitor 84, and supplies a predetermined fraction of said voltage, through conductors 117 and 118 to a voltage comparing and error signal amplifying circuit 119 including a source 120 of stable reference voltage which in the illustrated embodiment takes the form of a Zener diode, but which may take any other suitable form, such as a Mercury battery or a standard cell. When the voltage supplied to the storage capacitor 84 is of the proper value, the fraction thereof supplied to the circuit 119 substantially matches the voltage supplied by the stable voltage source 120.

The voltage comparing and error signal amplifying circuit 119 supplies to a second amplifying circuit 121, through conductors 122 and 123, a current signal which varies inversely with variations in the sampled voltage with respect to the stable voltage source 120. Upon amplification in the circuit 121, this signal is supplied, through conductors 125 and 126, to variable impedance means 124, which may take the form of a saturable reactor. The saturable reactor 124 has load and control windings 127 and 128 respectively, the load winding 127 being connected in parallel circuit relation with the control winding 129 of a load reactor 130 and also with a reset capacitor 131. The load reactor also has a load winding 132 which, with the control winding 129 is wound on an iron core which preferably has substantially rectangular hysteresis curve characteristics affording maximum changes in impedance in the load winding for a given current change in the control winding. The load winding 132 is interposed in the conductor 40 between the power transformer 77 and the conductor 83 as shown. Power is supplied to the circuits 119 and 121 from a transformer 133 having a primary winding 134 supplied from the source 76 through conductors 135 and 136 connected to the conductors 78 and 79 respectively as shown. The transformer 133 has secondary windings 137 and 138 connected respectively into the circuits 121 and 119 as shown.

The circuit 121, variable impedance means 124, reset capacitor 131 and load reactor 130 comprise error signal sensitive variable impedance means for supplying impedance to the charging circuit for the storage capacitor 84 as required to adjust the voltage at said capacitor to the predetermined proper value. The variable impedance means 124 and reset capacitor 131 provide means for resetting and reorienting the iron of the core of the load reactor 130 during the intervals between successive current pulses through the load winding 132. Thus the interval between successive current pulses must be of sufficient duration to permit such resetting. The half wave rectifier 81 is uniquely suited to provide unidirectional pulses spaced sufficiently to permit resetting of the

core iron during the intervals between successive pulses. The degree of resetting, and hence the magnitude of the impedance afforded to current flow through the winding 132, is variable in accordance with the impedance of the variable impedance means 124. The impedance of the variable impedance means 124, i.e. the impedance of load winding 127 thereof, is variable inversely with variations in the amplified signal supplied to the windings 128 from the circuit 121.

The flow of a direct current pulse through the load winding 132 of load reactor 130 effects a predetermined orientation of the molecular structure of the iron of the core of said reactor and simultaneously induces a voltage in the control winding 129, which voltage is impressed upon the reset capacitor 131, charging the latter. This action affords a predetermined impedance to the flow of the direct current pulse through the winding 132. On termination of the direct current pulse aforementioned, the capacitor 131 tends to discharge through the load reactor control winding 129, as well as through the saturable reactor load winding 127. Current flow from the capacitor 131 through the winding 129 of reactor 130 is effective to reset or reorient the molecular structure of the core of said reactor, and the degree to which the iron of said core is reset is determinative of the impedance to flow through the winding 132 presented to the next succeeding direct current pulse.

The percentage of the stored energy in the reset capacitor 131 which can discharge through the load reactor winding 129 is dependent upon the impedance presented by the saturable reactor winding 127 to the flow of said discharging current therethrough. Since the impedance presented to current flow through the winding 127 is variable inversely with the magnitude of the signal supplied to the windings 128, and the signal supplied by the voltage comparing circuit 119 to amplifying circuit 121 varies inversely with variations in the sampled voltage, if the voltage supplied to the storage capacitor 84 exceeds the desired predetermined voltage, the impedance to current flow through the saturable reactor load winding 127 is correspondingly increased. This causes a greater percentage of the stored energy in the reset capacitor 131 to discharge through the load reactor control winding 129, thereby increasing the degree of resetting of the iron of the load reactor core and correspondingly increasing the impedance presented to the next direct current pulse through the load reactor load winding 132.

The increase in impedance to current flow through the load winding 132 of the load reactor reduces the current flow into the storage capacitor 84 on the next succeeding pulse such that the recharge current is less than the drain of the voltage sampling network 112 until the charge in the capacitor 84 decays to the predetermined desired value. Conversely, in the event that the voltage to which the storage capacitor 84 is subjected drops below the desired value, the impedance to current flow through the saturable reactor load winding 127 is decreased, so that a greater percentage of the stored energy in the reset capacitor 131 can discharge therethrough, leaving a smaller percentage to flow through the load reactor control winding 129. This affords a lesser degree of resetting of the iron of the load reactor core, so that on the next succeeding current pulse through the load reactor load winding 132, less impedance is presented to the flow thereof, and the voltage to which the storage capacitor 84 is subjected is returned to the predetermined desired value.

With the improved circuitry just described, the voltage to which the storage capacitor 84 is subjected can be maintained within $\pm 2\%$ of the predetermined desired voltage, in spite of voltage changes at a normally 115 volt source 76 of from 105 to 125 volts. Similar control is possible where the source 76 is normally of 200 volts.

Variations in graphic originals, for example as between black and white and colored, or variations in the types of

heat-sensitive copying papers used necessitate the provision of means for adjusting the energy level of the radiation pulse produced by the lamp 35. Copying of a black and white original, for example, takes less radiation than does copying an original including other colors. Manual adjustment of the energy level of radiation available from the lamp 35 is afforded by a rotary knob 139 on the front of the casing 5 (see FIGURE 1) directly controlling the adjustment of the potentiometer 115 in the voltage sampling circuit 112. By this adjustment, the sampled voltage supplied to the voltage comparing circuit 119 through conductors 117 and 118 is a larger or smaller fraction of the total voltage impressed upon the storage capacitor 84. Since the voltage control means supplies impedance to the charging circuit as required to maintain the voltage impressed on the capacitor 84 at a value such that the sampled voltage substantially matches the stable reference voltage, adjustment of the potentiometer 115 by rotation of the knob 139 adjusts the voltage at the storage capacitor 84 to a new level which is automatically maintained by said voltage control means.

Having thus described the structure and organization of thermoprinting apparatus illustrating one specific embodiment of the present invention, it is to be understood that the illustrated form was selected to facilitate the disclosure of the invention, rather than to limit the number of forms which it may assume. Various modifications, adaptations, and alterations may be applied to the specific form shown to meet the requirements of practice without in any manner departing from the spirit or scope of the present invention, and all of such modifications, adaptations, and alterations are contemplated as may come within the scope of the appended claims.

What is claimed as the invention is:

1. In combination, an energizing circuit having a direct current portion including a rectifier connected to a first source of alternating current and to a capacitor for supplying electrical energy from said source to said capacitor in rectified direct current form, and means for controlling the direct current flow to said capacitor through said circuit portion to thereby insure storage of a predetermined magnitude of electrical energy in said capacitor irrespective of fluctuations in the voltage at said first source, said means comprising, means for sampling the voltage supplied to said capacitor, a source of stable reference voltage, means for comparing the sampled voltage with said reference voltage and for generating an error signal in the event of a mismatch therebetween caused by a departure of the voltage at said capacitor from said predetermined value, and error signal sensitive variable impedance means including a saturating load reactor having a control winding operatively associated with said voltage comparing means and having a load winding inductively coupled to said control winding and connected into said direct current portion of said energizing circuit for varying the impedance in said circuit portion as required to adjust the voltage at said capacitor to said predetermined value.

2. In combination, an energizing circuit in which electrical energy is supplied to a given load from a first source, and means for maintaining the voltage of the electrical energy supplied to said load through said circuit at a predetermined value irrespective of fluctuations in the voltage at said first source, said means comprising, means for sampling a predetermined fraction of the voltage supplied to said load, a source of stable reference voltage, means for comparing the sampled voltage with said reference voltage and for generating an error signal in the event of a mismatch therebetween caused by a departure of the voltage at said load from said predetermined value, means including a saturable reactor having load and control windings connected in circuit with said voltage comparing means to receive and amplify an error signal therefrom, capacitor means connected in parallel circuit relation with the load winding of said saturable

reactor, a load reactor having load and control windings, said load reactor control winding being connected in parallel circuit relation with the saturable reactor load winding, and said load reactor load winding being connected into said energizing circuit in series with said first source and said load for varying the impedance in said energizing circuit as required to adjust the voltage at said load to said predetermined value.

3. In a machine for reproducing graphic originals in which a composite of a graphic original and a copy sheet is subjected to brief intense irradiation, the combination of a flash lamp, a storage capacitor in circuit with said flash lamp, a charging circuit having a direct current portion including a rectifier connected to a first source of alternating current and to said capacitor for supplying electrical energy from said source to said capacitor in rectified direct current form, means for causing discharge of said capacitor through said lamp and generation of a radiation pulse, and means for maintaining the voltage supplied to said capacitor by said charging circuit at a predetermined value to thereby insure uniformity of the peak intensity of successive radiation pulses irrespective of variations in the voltage at said first source, said means comprising, means for sampling a predetermined fraction of the voltage supplied to said storage capacitor, a second source of stable reference voltage, means for comparing the sampled voltage with said reference voltage and for generating an error signal in the event of a mismatch therebetween caused by a departure of the voltage at said storage capacitor from said predetermined value, means for amplifying said error signal, and a saturating load reactor having a control winding in circuit with said amplifying means and having a load winding inductively coupled to said control winding and connected into said direct current portion of said charging circuit for varying the impedance in said charging circuit portion as required to adjust the voltage at said capacitor to said predetermined level.

4. In a machine for reproducing graphic originals in which a composite of a graphic original and a copy sheet is subjected to brief intense irradiation, the combination of a flash lamp, a storage capacitor in circuit with said flash lamp, a charging circuit for said storage capacitor powered by a first source, means for causing discharge of said capacitor through said lamp and generation of a radiation pulse, and means for maintaining the voltage supplied to said capacitor by said charging circuit at a predetermined value to thereby insure uniformity of the peak intensity of successive radiation pulses irrespective of variations in the voltage at said first source, said means comprising, means for sampling a predetermined fraction of the voltage supplied to said storage capacitor, a source of stable reference voltage, means for comparing the sampled voltage with said reference voltage and for generating an error signal in the event of a mismatch therebetween caused by a departure of the voltage at said storage capacitor from said predetermined value, means including a saturable reactor having load and control windings connected in circuit with said voltage comparing means to receive and amplify an error signal therefrom, capacitor means connected in parallel circuit relation with the load winding of said saturable reactor, a load reactor having load and control windings, said load reactor control winding being connected in parallel circuit relation with the saturable reactor load winding, and said load reactor load winding being connected into said charging circuit in series circuit with said first source and said storage capacitor for varying the impedance in said charging circuit as required to adjust the voltage at said storage capacitor to said predetermined level.

5. In combination, a first circuit having means establishing unidirectional current flow therethrough in spaced pulses, a control circuit, and means for varying the current flow in said first circuit in accordance with variations in current flow in said control circuit, said means comprising a load reactor having an iron core and having load and

control windings, said load winding being connected into said first circuit, variable impedance means operatively related to said control circuit and operable to afford impedance varying in accordance with variations in the current flow through said control circuit, said variable impedance means being connected in circuit with said control winding, and capacitor means connected in circuit with said control winding and variable impedance means to be chargeable by current flow induced into said control winding by current pulses in said first circuit and dischargeable through said variable impedance means and said control winding in the intervals between said pulses to thereby reset the iron of said reactor core, variations in the impedance of said variable impedance means in response to variations in the current flow in said control circuit effecting a variation in the percentage of the capacitor charge discharged through said control winding to thereby afford variation in the degree of resetting of the reactor core effected by such discharge and hence in the amount of impedance in said first circuit by said load winding on the next succeeding current pulse in said first circuit.

6. In combination, a first circuit having means establishing unidirectional current flow therethrough in spaced pulses, a control circuit, and means for varying the current flow in said first circuit in accordance with variations in current flow in said control circuit, said means comprising a load reactor having an iron core and having load and control windings, said load winding being connected into said first circuit, variable impedance means operatively related to said control circuit and operable to afford impedance varying in accordance with variations in the current flow through said control circuit, said variable impedance means being connected in parallel circuit relation with said control winding, and capacitor means connected in parallel circuit relation with said control winding and variable impedance means, said capacitor means being chargeable by current flow induced into said control winding by current pulses in said first circuit and dischargeable through said variable impedance means and said control winding in the intervals between said pulses to thereby reset the iron of said reactor core, variations in the impedance of said variable impedance means in response to variations in the current flow in said control circuit effecting a variation in the percentage of the capacitor charge discharged through said control winding to thereby afford variation in the degree of resetting of the reactor core effected by such discharge and hence in the amount of impedance in said first circuit by said load winding on the next succeeding current pulse in said first circuit.

7. In combination, a first circuit having means establishing unidirectional current flow therethrough in spaced pulses, a control circuit, and means for varying the current flow in said first circuit in accordance with variations in current flow in said control circuit, said means comprising a load reactor having an iron core and having load and control windings, said load winding being connected into said first circuit, a second reactor having a load winding and having a control winding connected into said control circuit, the impedance afforded by said second reactor load winding being variable in accordance with variations in the current flow through said control circuit, said second reactor load winding being connected in parallel circuit relation with said load reactor control winding, and capacitor means connected in parallel circuit relation with said load reactor control winding and said second reactor load winding, said capacitor means being chargeable by current flow induced into said load reactor control winding by current pulses in said first circuit and dischargeable through said second reactor load winding and said load reactor control winding in the intervals between said pulses to thereby reset the iron of said load reactor core, variations in the impedance of said second reactor load winding in response to variations in the current flow in said control circuit effecting a variation in

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the percentage of the capacitor charge discharged through said load reactor control winding to thereby afford variation in the degree of resetting of the load reactor core effected by such discharge and hence in the amount of impedance in said first circuit by said load reactor load winding on the next succeeding current pulse in said first circuit.

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