United States Patent

[11] **3,619,720**

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[54] **ELECTRICALLY ASSISTED PRINTING SYSTEM**
1 Claim, 4 Drawing Figs.

[52] **U.S. Cl.** **317/3,** 101/153, 101/170
[51] **Int. Cl.** **B41f 9/06,** B41m 5/20
[50] **Field of Search** 101/150, 153, 426, 170; 317/3, 262, 149

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ABSTRACT: A printing system having an electric circuit supplying an output potential to assist transfer of ink to a dielectric substrate, the potential being gradually increased up to a breakdown potential of the substrate, for example of a rate of 10 percent per hour. Each time breakdown potential is reached, the applied potential is set back 10 percent and the increase started again, so that the applied potential will follow variations in the breakdown potential of the substrate. A severe fault in the substrate results in removal of the output potential during a timed interval followed by a rapid potential buildup toward breakdown potential, after which the normal cycle is resumed.

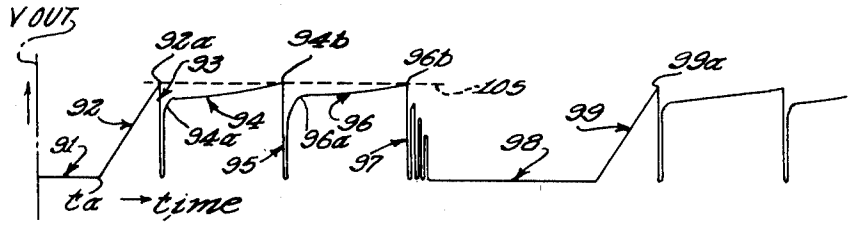


Fig. 1a

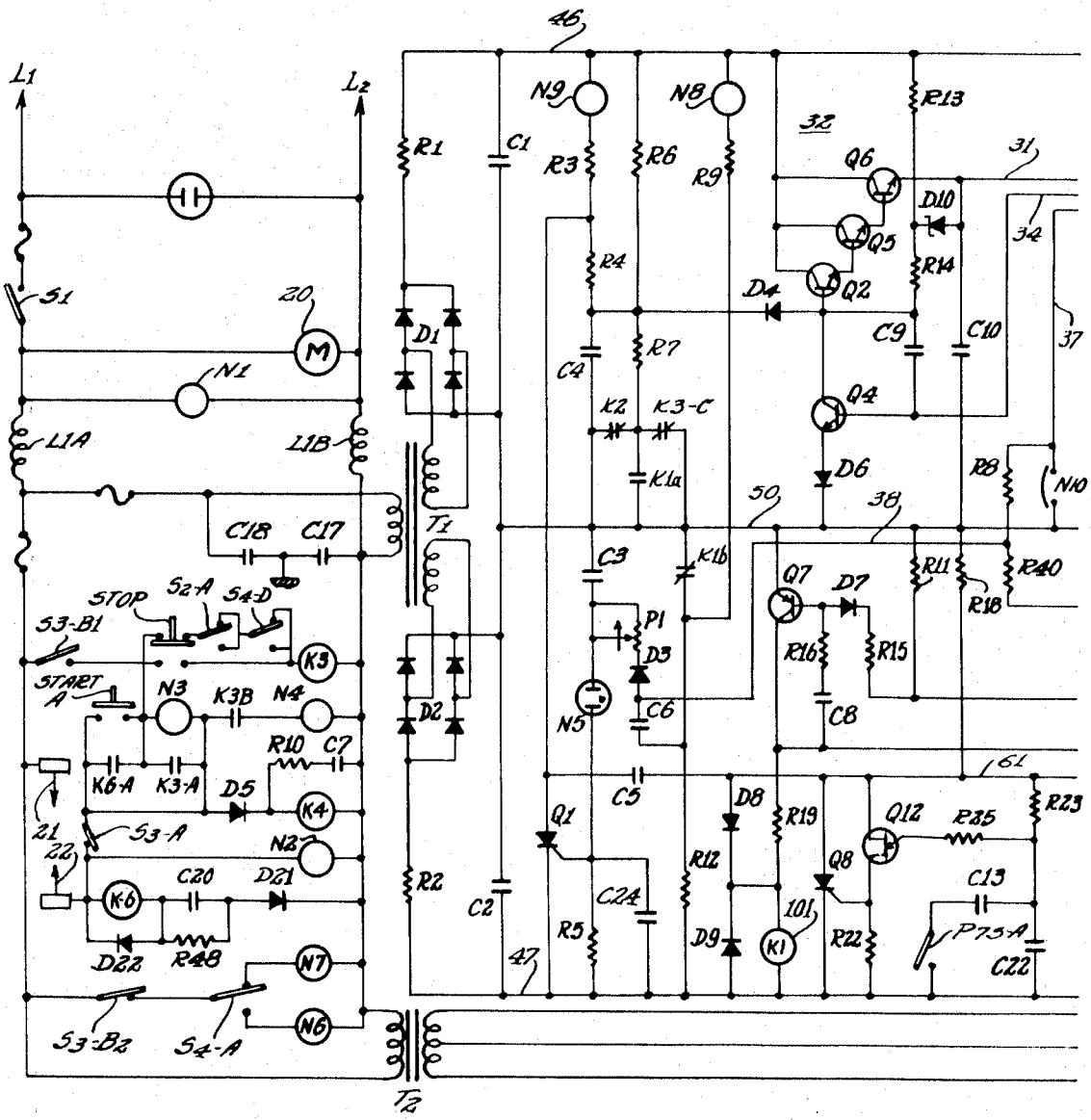
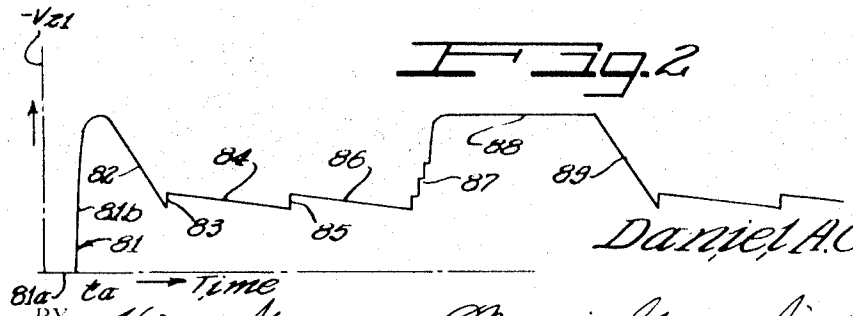


Fig. 2



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Fig. 1b

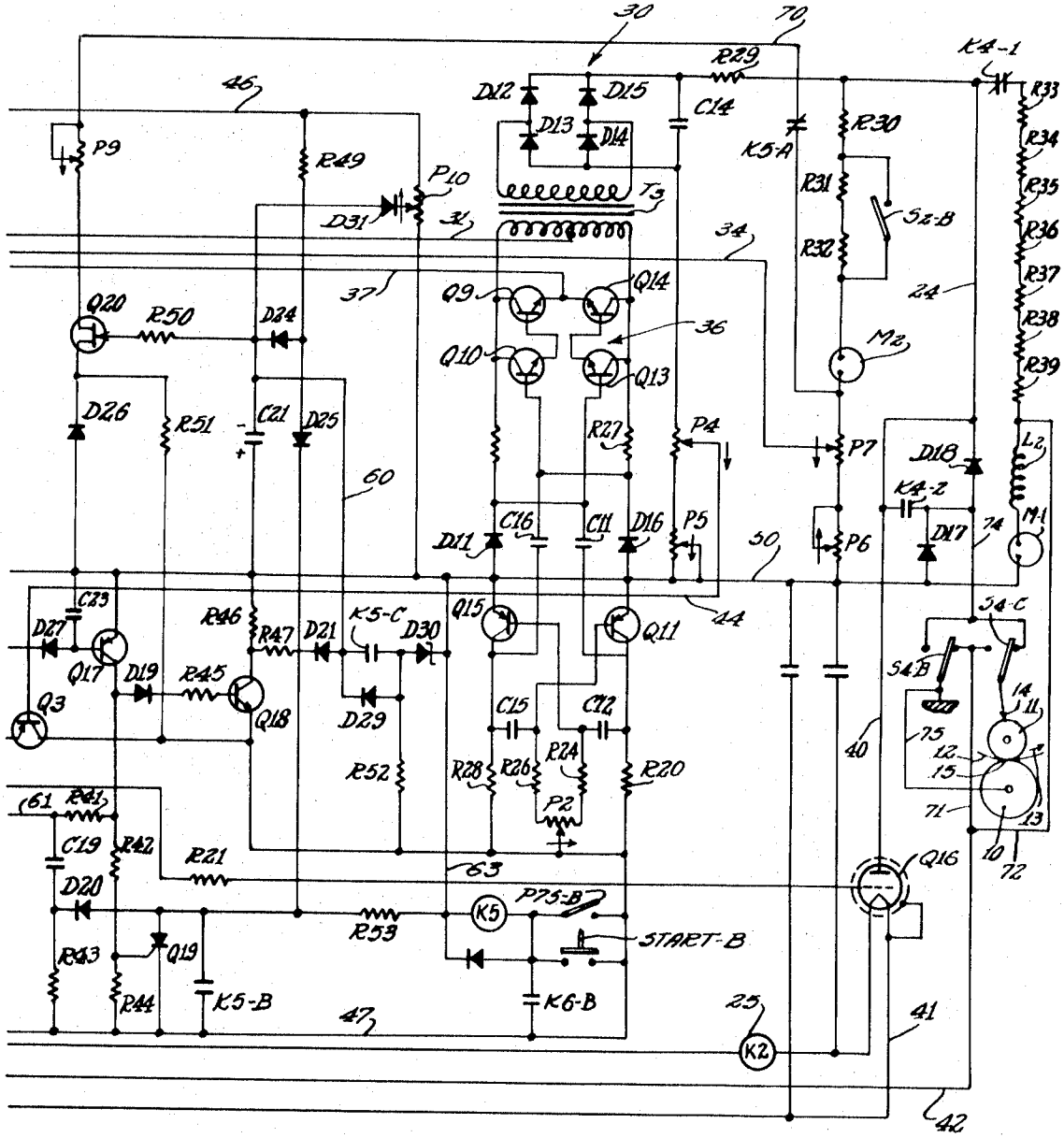
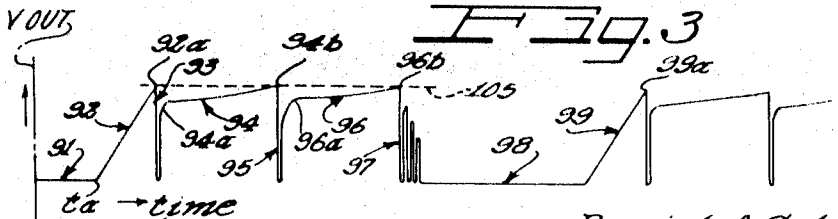


Fig. 3



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ELECTRICALLY ASSISTED PRINTING SYSTEM

SUMMARY OF THE INVENTION

This invention relates to an electric printing system and method and particularly to such a system wherein an applied electric potential across a moving dielectric substrate assists in transfer of ink to the substrate.

An object of the invention is to provide an improved electrical printing system and method.

Another object is to provide an improved electric circuit for maintaining substantially an optimum applied electric potential for assisting in the transfer of ink to a dielectric substrate.

A further object of the invention is to provide an electric printing system wherein the applied potential is maintained near the breakdown potential of the substrate in spite of any variations thereof during normal operation.

A feature of the invention resides in the provision of an electric circuit for generally increasing the applied potential in an electric printing system up to a breakdown potential value, the applied potential being set back a predetermined amount each time the breakdown potential is approached so that the applied potential essentially follows variations in the dielectric strength of the printing medium during normal operation.

A subsidiary feature resides in the provision of a start cycle wherein the potential applied by said electric circuit is initially increased at a substantially higher rate so as to relatively rapidly approach the optimum operating range.

Another subsidiary feature resides in the provision of means for removing the output potential in response to a serious fault in the printing substrate and then increasing the applied potential at a relatively rapid rate after a predetermined time delay.

Other objects, features and advantages of the invention will be readily apparent from tee following description of a preferred embodiment thereof, taken in conjunction with the accompanying drawings although variations and modifications may be effected without departing from the spirit and scope of the novel concepts of the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1*a* and 1*b* together illustrate a preferred electric circuit in accordance with the present invention. FIG. 1*b* being a continuation of the circuit of FIG. 1*a* to the right;

FIG. 2 illustrates an exemplary operating sequence for the electric circuit of FIGS. 1*a* and 1*b* and specifically represents the magnitude of the negative potential across the capacitor C21 of FIG. 1*b*; and

FIG. 3 illustrates the output electric potential variation for the sequence of operation illustrated in FIG. 2, the time scale in FIG. 3 corresponding to the time scale in FIG. 2.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1*b*, the electric circuit has been illustrated as applied to a gravure-type printing system including a gravure cylinder **10**, an impression roller **11** and a dielectric substrate **12** moving in the direction of the arrow **13** through a printing nip between the gravure cylinder and impression roller. In a commercial printing system of this type, the gravure cylinder **10** may be of electrically conductive metal, while the impression roller **11** may have a metal core with a layer of insulating rubber and an outer covering of semiconductive rubber to which an electric potential is applied by means of a conductive roller or the like as represented by the contact **14**. The applied potential produces an electric current flow in the covering of semiconductive rubber so as to continuously supply electrical energy at the nip region indicated at **15** between the gravure cylinder **10** and impression **11**. Typically sufficient downward force is applied by the impression roller **11** so as to result in a force of 50 to 100 pounds for each lineal inch along the length of the nip region **15** (at right angles to the direction of travel of the substrate **12**). In the illustrated embodiment, a direct current potential is applied, but it is contemplated that an alternating current potential may also be employed. The invention is not limited to a gravure printing system but is applicable also to other types of printing.

Referring to the left hand side of FIG. 1*a*, a switch **S1** supplies commercial 60-hertz electric power to the system, energizing a fan motor **20** and a neon "power" indicator **N1**. The input is isolated by inductors **L1A** and **L1B** and capacitors **C17** and **C18** to prevent transients from triggering a crowbar cycle (to be hereinafter described).

Depressing the start button closes contacts "Start A" shown at the left center of FIG. 1*a* and also closes the contacts "-Starts B" shown at the lower right of FIG. 1*b*. Energization of relay **K6** simulates momentary pressing of the start button each time the external press "go-down" circuit is completed between contacts **21** and **22** at the lower left of FIG. 1*a*. Each time the circuit between contacts **21** ad **22** is completed indicating that the printing substrate **12** is moving at proper speed, relay **K6** is momentarily actuated as capacitor **C20** is charged. When the capacitor **C20** reaches a predetermined charge, relay **K6** is then deenergized releasing the contacts **K6–A** and **K6–B** which parallel the A and B start contacts. A holding circuit for relay **K3** exists through contacts **S4–D**, **S2–A**, the stop switch contacts and contacts **K3–A** and through **S3–A** and through the "go-down" circuit between contacts **21** and **22**.

Relay **K4** connects the output at **24** in FIG. 1*b* to the press (specifically to the impression **11** and printing cylinder **10**) via normally open contact **K4–2** of relay **K4**. It will be noted that by reversing selector switch **S4**, contacts **S4–B** and **S4–C** will connect the positive output conductor **24** with the grounded gravure cylinder **10**, rather than to the impression roller **11** as in the illustrated position of the selector switch **S4**. When relay **K4** is deenergized, the normally closed contacts **K4–1** at the upper right of FIG. 1*b* connect the output of the dummy load resistors **R33–R39**. Relay **K4** can only be energized if the mode switch **S3** is actuated to the "operate " position, closing contact **S3–A** shown at the lower left in FIG. 1*a*.

The setup relay **K3** has contacts **K3–C** as indicated in the central part of FIG. 1*a* which must be open to allow operation of the series regulator including transistors **Q2**, **Q5** and **Q6**. Either one of two setups may latch **K3**. In "test," the mode switch **S3** is in "test" position and the "stop" button is latched in the lower position to energize relay **K3** through contact **S3–B1** and "stop" contacts of the stop button. In the "operate" position of the mode switch **S3** the external "go-down" circuit between **21** and **22** is completed and either the start button is momentarily depressed or the "go-down" setup relay **K6** is momentarily energized.

The range switch **S2** and the polarity switch **S4** each have a pole (**S2–A** and **S4–D**) in series with the setup relay **K3** to unlatch the relay at each new selection.

Relay **K2** whose energizing coil is indicated at **25** at the lower right in FIG. 1*b* is the filament relay. The **K2** coil **25** is in series with the filament circuit of the thyratron **Q16** shown at the lower right in FIG. 1*b*, and will be energized only if the filament circuit draws current. Relay **K2** has a single set of contacts **K2'** which in the normally closed condition holds the series regulator **Q2**, **Q5**, **Q6** in the "off" condition when relay **K2** is deenergized.

Current to the high-voltage generator indicated generally at **30** (at the upper part of FIG. 1*b*) is supplied via line **31** and is controlled by the input to transistor **Q2** of regulator **32** (the upper right of FIG. 1*a*). Zener diode **D10** and resistors **R13** and **R14** control the supply of a constant current to the regulator **32**, a comparison amplifier provided by transistor **Q4**, and a reference diode **D6**. Feedback voltage from resistor divider **R30**, **R31**, **R32**, **P7** and **P6** (at the upper right of FIG. 1*b*) is supplied via conductor **34** to the input of the comparison amplifier **Q4** and is compared with the reference voltage across diode **D6**. As feedback is increased, transistor **Q4** bypasses a larger portion of the constant current away form the series regulator **32**. Thus the regulator output decreases the subsequent voltage across the resistor divider until stabilization is

reached. Hence adjustment of the resistor divider ratio by means of S2–B, P6 and P7 governs the output voltage at output 24. Capacitor C4 and resistor R6 form an RC ramp circuit to limit the turn on rise time of the regulator. If any of the relay contacts K2', K3–C and K1*a* are closed, the capacitor C4 will be held to essentially a zero voltage thereacross. Diode D4 will clamp the input of series regulator 32 to the voltage across capacitor C4 and thus will hold the regulator 32 to the voltage across capacitor C4 and thus will hold the regulator 32 open when any of the contacts K2, K3–C and K1*a* are closed. If all of these relay contacts are open, capacitor C4 will charge and the clamping diode D4 will follow and bring the regulator 32 along. When the regulator reaches stabilization, the capacitor C4 will continue to charge and will reverse bias diode D4.

Transistors Q15 and Q11 at the center part of FIG. 1*b* form an oscillator with the associated passive components. The oscillator is an astable multivibrator running at approximately 1,000 hertz. Potentiometer P2 serves as a symmetry balance. The oscillator is constructed of PNP transistors and operates from the negative supply to achieve low output impedance to drive bistable multivibrator 36. The oscillator runs continuously.

Bistable multivibrator 36 uses transistors Q9, Q10, Q13 and Q14, and drives transformer T3 with a square wave of varying amplitude dependent on the regulator input power to the bistable via conductor 31. Emitter current passes through a bimetal breaker N10 via conductor 37, the component N10 appearing at the right center of FIG. 1*a* and serving to prevent excessive generator current. The voltage drop across the breaker when the breaker opens is supplied via resistor R8 and conductor 38 to a safety circuit including capacitor C3, neon tube N5 and silicon controlled rectifier Q1. Thus circuit operates to remove the output potential from output conductor 24 for a predetermined time interval when the circuit breaker opens. As will hereinafter be described, the same circuit averages crowbar pulses by means of capacitor C3 and trips the time delay at a preset average. The time delay circuit including transistor Q12 and silicon controlled rectifier Q8 at the lower right of FIG. 1*a* delays the supply of power to the high voltage generator each time the system is turned on, and each time the safety circuit is tripped. The crowbar circuit including the thyratron Q16 at the lower right of FIG. 1*b* responds to excess current flow in potentiometer P4 at the center part of FIG. 1*b* to render the thyratron Q16 conductive in response to output current flow in excess of normal in the system so as to immediately short circuit the output 24 via conductor 40, thyratron Q16 and conductors 41 and 42. This discharges the press components 10 and 11 and prevents any further power from being delivered thereto. It interrupts the power supply to the press for the time that the web defect is in the printing nip 15. The amount of current rise which will trigger the crowbar circuit is adjustable by means of the current trip set control which controls potentiometer P4 associated with crowbar feedback conductor 44 at the center of FIG. 1*b*.

Transformer T1 at the center of FIG. 1*a* has two secondary windings supplying rectifier bridges D1 and D2. Bridge D1 together with resistor R1 and capacitor C1 supplied approximately 3 amperes at plus 50 volts direct current to the regulator 32 via conductor 46. Bridge D2 together with resistor R2 and capacitor C2 supplies approximately one-half ampere at minus 50 volts direct current to conductor 47.

The maximum output power of the transformer T3 at the upper center of FIG. 1*b* is approximately 7 kilovolts at 7 milliamperes. Rectifiers D12, D13, D14 and D15 and capacitor C14 convert the power to direct current. Resistor R29 serves as a plate load resistor for thyratron Q16 during the crowbar function and serves as a limit resistor during regular operation to isolate capacitor C14 from the output. Diodes D17 and D18 clamp the output conductor 24 of the high-voltage generator 30 to the return line 50 when no power is being applied to the press components 10 and 11.

Potentiometers P4 and P5 connect return conductor 50 to the negative side of the high-voltage generator 30. Current drawn by the press components 10 and 11 will appear as a negative voltage across the potentiometers. As previously mentioned, a portion of this voltage is fed back by means of conductor 44 to the crowbar input circuit at the base of transistor Q3.

The crowbar circuit consists of transistors Q3 and Q7, relay K1 (at the lower right of FIG. 1*a* and the thyratron Q16. Transistor Q3 which forms the first stage of the crowbar circuit is an emitter follower, so that the output voltage essentially equals the input voltage. Diode D7, FIG. 1*a* which is connected to the emitter of Q3 insures that the transistor Q7 will turn full off when the signal from Q3 is removed. When press current increases, diode D7 will be forward biased and transistor Q7 will conduct an amount preset by potentiometer P4. Resistor R16 and Capacitor C8 in the base circuit of Q7 average the output of transistor Q7 by the Miller effect. If transistor Q7 is off (nonconducting), no voltage will be developed across the relay energizing coil of relay K1. Hence, the thyratron Q16 is held off by the negative supply through the relay coil of K1. If for example an arc occurs between press components 10 and 11, transistor Q7 turns on very quickly. The coil of relay K1 appears as a high impedance and the grid voltage of thyratron Q16 is bypassed to the common return line 50, thus allowing the thyratron to fire in approximately 10 microseconds. The thyratron shorts across the press components 10 and 11 and applies a heavy load to the high-voltage generator 30. Hence more current flows in potentiometer P4 and results in saturation of transistor Q7 until relay K1 has energized (in approximately 5 milliseconds).

Relay K1 has snap action single pole double throw contacts K1*a* and K1*b* shown at the center of FIG. 1*a*. The normally open contacts K1*a* are in parallel with contacts K2' and K3–C to also turn on and off the regulator 32. Energization of the K1 relay turns off the regulator 32, thus removing power to the high-voltage generator and allowing the thyratron Q16 to reset. Since current flow in potentiometer P4 has ceased, the input signal at conductor 44 at the input to the crowbar amplifier is removed, and the crowbar relay K1 is deenergized. This then completes one cycle of the crowbar circuit.

The safety circuit involves silicon-controlled rectifier Q1, trigger neon N5, capacitors C3 and C6, and the normally closed contacts K1*b* of the K1 relay. Each time the crowbar circuit cycles, the K1*b* contacts open and close to actuate the fault indicator N8 and to supply a negative-going square wave to capacitor C6. Capacitor C6 produces a negative going pulse at conductor 38 in response to the leading edge of the square wave and supplies a positive pulse in response to the trailing edge. The negative pulse is routed via conductor 38, resistor R40 and diode D27 to actuate transistor Q17. The positive pulse is supplied via diode D3 and potentiometer P1 to capacitor C3. The averaging of the charge supplied to capacitor C3 is adjusted by means of the potentiometer P1. If the average of the positive pulses supplied to capacitor C3 is high enough, the neon N5 breaks over and fires the safety silicon-controlled rectifier Q1.

The safety silicon-controlled rectifier Q1 performs the following functions: one, it fires the safety indicator N9; two, it opens the regulator 32 by discharging capacitor C4 through resistor R4; and three, it commutates the time delay silicon-controlled rectifier Q8 through commutating capacitor C5.

The time delay circuit uses a unijunction transistor Q12, a time delay silicon-controlled rectifier Q8 and crowbar relay K1. The base two reference and charging voltage to capacitor C22 are both taken from the anode of Q8. If Q8 is nonconducting, diode D8 will be forward biased and energize the crowbar relay K1 from common conductor 50 through resistor R18. The voltage drop across the relay K1 will serve as the input voltage to the time delay transistor Q12. When Q8 is conducting through resistor R18, diode D8 is reversed biased and the relay K1 is under the control of crowbar transistor Q7. When Q8 is conducting, it commutates Q1 to the nonconduct-

ing condition by means of capacitor C5, and it commutates the automatic advance silicon-controlled rectifier Q19 at the lower left of FIG. 1*b* to the nonconducting condition by means of capacitor C19 at the lower left of FIG. 1*b*. The shut down of series regulator 32 on each safety trip has redundant control since Q1 turns off the regulator via resistor R4 while Q8 turns off the regulator through relay K1, thus doubly insuring shut down in case of component failure.

In the automatic mode, an automatic voltage adjustment transistor Q20 at the upper left of FIG. 1*b* and a rheostat P9 are placed across the feedback potentiometer P7 and trimmer potentiometer P6, the potentiometer P7 being fully counterclockwise so as to hold contacts P7U–A (at the lower right FIG. 1*a*) and contacts P7S–B (at the lower center of FIG. 1*b*) in the open condition as shown. Transistor Q20 is a junction field effect transistor used as a variable resistor. This permits electronic adjustment of the voltage divider ratio which is supplied via conductor 34 to the input of the series regulator 32. Accordingly, control of the transistor Q20 will serve to control the output voltage at output conductor 24. The high input impedance of Q20 and low leakage of capacitor C21 and diodes D21 (at the center left of FIG. 1*b*), D24 and D29 (at the lower center of FIG. 1*b*) allow the capacitor C21 to control the output voltage of the generator 30 over extended periods of time with little drift. The reverse current of diodes D31 (at the upper left of FIG. 1*b*) and D21 compensate the coefficients of diodes D24 and D29, respectively. A small negative offset voltage is utilized from resistor R51 and diode D26 to insure sufficient turn on of transistor Q20. The output voltage at conductor 24 is inversely proportional to the charge on capacitor C21, consequently leakage from capacitor C21 results in a long term increase in the output voltage at conductor 24 during automatic operation.

Capacitor C21 acquires a charge from two independent circuits. If the unit is in manual mode, capacitor C21 is charged to the voltage of zener diode D30 (at the lower center of FIG. 1*b*) from conductor 47 through R52, contacts K5–C and conductor 60. Relay K5 may be energized by actuation of potentiometer P7 to momentarily close contacts P7S–B.

If the unit is in automatic mode and is recycled, the turn off of Q8 provides a relatively high input potential at the base of Q18 (from common conductor 50 via R18, conductor 61, R41, D19 and R45) so as to render Q18 conducting for the duration of the timing cycle, allowing charging of capacitor C21 from the negative conductor 47 through Q18, R47, D21 and conductor 60.

The automatic setback amplifier Q17 at the center left of FIG. 1*b* amplifies each negative pulse received from the crowbar relay contacts K1*b* via capacitor C6, and each pulse passes on to the automatic switching transistor Q18 which will conduct and allow charging of capacitor C21 for the duration of each such negative pulse to amplifier Q17. By way of example, the charge supplied to capacitor C6 may reduce the voltage to output conductor 24 by approximately 10 percent. Thus in response to each crowbar cycle, capacitor C21 receives an increment of charge sufficient to reduce the output voltage from the circuit by about 10 percent. When, however, the safety circuit is actuated by capacitor C3, capacitor C21 is recharged to a voltage determined by zener diode D30, which charge corresponds to a selected lowest operating output voltage at conductor 24 (after the safety cycle has been completed and thyratron Q16 reset).

The switching transistor Q18 is held in a conducting state if the time delay silicon-control rectifier Q8 is nonconducting through resistor R41 and diode D19 during a safety cycle as previously described. The diode D19 insures that the forward drop when the time delay silicon-controlled rectifier Q8 is conducting will not hold transistor Q18 in the conducting condition. Diode D21 is an isolation diode. The switching transistor Q18 causes charging of capacitor C21 from the minus 50 volt supply conductor 47 for improved linearity. The clamping diode D29 will limit the charge on capacitor C21 to the zener voltage of D30.

At the end of a safety cycle, after capacitor C21 is fully charged, the automatic advance silicon-controlled rectifier Q19 (at the lower left of FIG. 1*b*) is rendered nonconducting, to permit capacitor C21 to discharge relatively rapidly through diode D24 and resistor R49 to the positive supply conductor 46. Diode D25 prevents the capacitor from charging positively by clamping the anode of diode D24 through resistor R53 and conductor 63 to the common conductor 50. When the automatic advance silicon-controlled rectifier Q19 is conducting, diode D25 is forward biased and diode D24 is reverse biased. Thus, no discharging current can flow through diode D24 once a safety cycle has been completed. Each time the time delay silicon-controlled rectifier Q8 fires, the automatic advance silicon-controlled rectifier Q19 is commutated off through commutating capacitor C19 and diode D20, so as to permit the rapid discharge of capacitor C21 and a corresponding relatively rapid increase of the output potential at conductor 24 from the minimum operating potential up to a desired operating level which as will hereinafter be explained will approach the dielectric breakdown strength of the printing medium 12 for the illustrated embodiment. Crowbar pulses from the setback amplifier Q17 are fed to the gate of the silicon-controlled rectifier Q19 through resistor R42, so that the first crowbar pulse after a safety cycle fires Q19 and stops the discharge of capacitor C21 at the relatively rapid rate. Diode D20 prevents commutation from the automatic advance SCR, Q19 back to the time delay SCR, Q8.

In accordance with the concepts of the present invention the high-voltage generator 30 is feedback controlled via conductor 34. The feedback voltage, however, is additionally controlled by the regulating line 70 appearing at the top of FIG. 1*b* and leading to the transistor Q20 whose effective resistance is controlled by the charge on capacitor C21. The output of the charging unit at 24 is supplied to components 10 and 11 to establish a current flow in the return circuit extending from component 10 via switch contact S4–B, conductor 71, conductor 72, inductor L2, ammeter M1, return conductor 50, and potentiometers P5 and P4. As the substrate 12 has a dielectric strength defined in volts per mil (1 mil equals 0.001 inch) thickness, the maximum potential that can be applied between components 10 and 11 is limited by the dielectric strength of the substrate 12. This factor will vary with thickness, relative humidity and moisture content of the substrate. Furthermore, the substrate under normal conditions is not perfect and does exhibit pin holes, minute variations in thickness and foreign particles that result in dielectric breakdown in the practical case prior to the dielectric breakdown of the perfect material. The dielectric breakdown of the substrate 12 physically ruptures the material and an arc or spark is created. This must be extinguished prior to the material leaving the ink transfer zone 15. If it is not, a hazardous condition is established due to the extremely hazardous (explosive) environment that inherently exists, for example in a gravure printing system. In accordance with the present invention, it is desired to establish a maximum electrostatic force on the ink at the ink transfer region 15, and accordingly it is desired to maintain the potential between press components 10 and 11 at a value near but not exceeding the dielectric strength of the material 12.

A previously described, when the dielectric strength of the substrate is exceeded, a sharp spike of current is drawn which is sensed at crowbar feedback conductor 44 as previously described. The current is developed by the discharge of the area of the impression roller 11 above the fault. The spike of current causes the thyratron Q16 to ignite and shunt the charging unit and the impression roller, so that the capacitor formed at the ink transfer zone is connected to ground in less than 100 microseconds. The circuit extends from the contact 14 of impression roller 11 through contact S4–C, conductor 74, contacts K4–2, conductor 40, thyratron Q16, conductors 41 and 42 and contact S4*b* which in turn is connected to the metal of the impression roller 10 as indicated by conductor 75. This action removes energy from the ink transfer zone and

extinguishes the arc before the substrate 12 leaves the nip region 15. Due to the imperfect nature of the substrate these faults are considered normal to the operation of the system.

Manual operation of the charging unit allows the operator to establish the potential of the ink transfer zone using these faults as an indication of the optimum operating potential, faults being indicated by indicator N8, for example. Due to environmental conditions and variations in substrates the optimum operating potential may change after a period of time and may either increase or decrease. Thus to carry out manual operation would require the operator to constantly monitor the equipment. As a fault established in the nip is not hazardous if it is contained within the ink transfer zone 15, it is conceived that such fault indications may be used to create an automatic system.

In the illustrated system, at start up or in a safety recycle operation, the output voltage at conductor 24 increases on a ramp function or linearly until the dielectric strength of the substrate 12 is exceeded and a fault or dielectric breakdown occurs. At this point, amplifier Q18 is rendered momentarily conducting, to supply an increment of charge to capacitor C21 so as to reduce the output voltage of the unit so that the unit supplies approximately 10 percent less voltage then the potential that resulted in breakdown. A second ramp is then initiated that increases the output potential at a much slower rate, for example by leakage of charge from capacitor C21 through the leakage resistance of diode D31 to the positive conductor 46, FIG. 1*b*. This discharge rate may be such that the output voltage at conductor 24 increases approximately 10 percent per hour. This second long ramp increases the voltage very slowly up to the maximum dielectric strength of the web 12. If the dielectric strength of the web has improved since the initial setting then the voltage will slowly increase until a new limit is established. If, however, the dielectric strength of the web has decreased, a series of faults occur during a short period of time and a safety cycle in initiated and after another period of time recharge capacitor C21 so that the unit will turn on at a selected lowest operating potential. Utilizing this cycling process, the optimum voltage is automatically maintained at the nip 15 without relying on a human operator and the consequent possibility of errors. In addition, it removes the possibility that in the over-voltage condition a hazard could be created in the pressroom.

Basically, what is done is to apply a potential high enough to result in the dielectric breakdown of the substrate 12 to be printed. The breakdown is sensed by the increased current in the system, for example, and the applied potential is then reduced for example to about 90 percent of the potential which produced the dielectric breakdown. By slowly increasing the potential thereafter, the potential "chases" the dielectric strength of the substrate. If a large imperfection occurs in the substrate, the equipment entirely removes the potential from the ink transfer zone 15 and repeats the initial cycle.

SUMMARY OF OPERATION

The operation of the illustrated embodiment may be summarized by referring to the operating sequence illustrated in FIGS. 2 and 3. FIG. 2 represents the quantity of charge or value of negative potential on capacitor C21, while FIG. 3 represents the corresponding output potential at conductor 24 relative to ground potential (as represented by conductor 75). FIGS. 2 and 3 are on a comparable time scale, but the illustration is purely diagrammatic and relative time intervals are not proportionately represented on the time base of FIGS. 2 and 3.

Referring to FIG. 2, successive operating cycles have been represented by the curve segments 81–89, while the corresponding output voltages have been represented in FIG. 3 by segments 91–99, respectively.

In the initial time interval from time zero to time t_a, capacitor C21 is represented as being charged from some arbitrary initial value such as zero up to its maximum negative potential as determined by the voltage of zener diode D30. The charging path is from the minus 50 volt conductor 47 through contacts K5–C and conductor 60 to capacitor C21 and then to the common return conductor 50. At this time relay K5 is energized (for example as a result of actuation of the start button to close contacts "Start B" at the lower part of FIG. 1*b*). Relay K3 will not be energized until the press reaches operating speed, so that prior to this time relay contacts K3–C are closed, disabling the regulator 32 and maintaining the output potential at zero as represented by the curve segment 91 in FIG. 3.

When the start button is released, relay K5 is deenergized, closing contacts K5–A at the upper right of FIG. 1*b* to enable the regulating circuit including conductor 70 and transistor Q20 which is controlled by the charge on capacitor C21. Once the system has reached operating speed, regulator 32 will supply energizing current via conductor 31, to the high-voltage generator 30, with the output voltage being controlled by means of the feedback line 34 to comparator Q4.

Contacts K5–B at the lower left in FIG. 1*b*, while closed, prevent conduction of silicon-controlled rectifier Q19, and Q19 remains nonconducting when relay K5 is deenergized. Accordingly, capacitor C21 has an effective discharge path to line 46 through D24 and R49, and discharges relatively rapidly as indicated at curve 82, FIG. 2. The output potential correspondingly increases as indicated at 92, FIG. 3. The rate of discharge of capacitor C21 may be relatively rapid, for example, corresponding to an output potential rise at 92 of the order of 2,000 volts per second.

When the output potential applied to the substrate 12 reaches a limiting potential value approaching the breakdown potential of the substrate as indicated at 92*a*, FIG. 3, the current in potentiometer P4 is such as to automatically trigger the crowbar amplifier Q3, Q7, and initiate a power interrupt cycle by rendering thyratron Q16 conductive. With energizing coil 101 of relay K1 energized, contacts K1*a* are closed, disabling regulator 32 and turning off high-voltage generator 30. At this time, current through potentiometer P4 is essentially zero, to restore thyratron Q16 to its its nonconducting condition. The negative pulse generated by opening and closing of contacts K1*b* of relay K1 results in the transmission of a negative-going pulse via capacitor C6, conductor 38, resistor R40 and diode D27 to render transistor Q17 momentarily conductive. This in turn renders silicon-controlled rectifier Q19 conductive, and adds a predetermined increment of charge to capacitor C21 (as indicated at 83 in FIG. 2) by virtue of the momentary conduction of transistor Q18.

The output potential now builds up to a reduced value as indicated at 94*a* which may be approximately 10 percent less than the limiting value as indicated at 92*a* in FIG. 3. The charge on capacitor C21 now leaks off at a greatly reduced rate as indicated at 84, FIG. 2, allowing the output potential to build up gradually as indicated by ramp waveform section 94 in FIG. 3.

When a limiting value as indicated at 94*b*, FIG. 3, is reached, a further power interrupt cycle ensues with the output potential being reduced to a value such as indicated at 96*a* at the end of the power interrupt cycle. The value 96*a* may be about 10 percent less than the limiting value 94*b*, and the output potential may again build up very gradually by virtue of leakage from capacitor C21 as represented by curve 86, FIG. 2.

If a succession of power interrupt cycles should be encountered as represented at 87 in FIG. 2, thyratron Q16 will become conductive, and regulator 32 will be held off during the conduction of silicon controlled rectifier Q1 as determined by the timing cycle of transistor Q12. This safety cycle is initiated when capacitor C3 acquires sufficient charge to cause neon tube N5 to become conducting.

While silicon-controlled rectifier Q8 is nonconducting (during the timing cycle of Q12), transistor Q18 is held conducting to allow charging of capacitor C21 to the maximum negative value as indicated at curve 88, FIG. 2. When Q8 becomes con-

ducting, Q19 is commutated to nonconducting condition, allowing capacitor C21 to be relatively rapidly discharged through D24 and R49 as indicated by curve 89, the output potential rising rapidly as indicated by curve 99 until it again reaches the neighborhood of the limiting potential value 99*a*, FIG. 3.

If the dash line 105 through the successive points of limiting potential such as 92*a*, 94*b*, and 96*b* represents essentially the variation of breakdown potential during a normal operating cycle, it will be observed that the operating potential is maintained essentially between this limit and the reduced values such as 94*a* and 96*a*, so that essentially the operating potential applied to the substrate during normal operation follows the dielectric breakdown strength of the substrate and is maintained sufficiently near the limiting potential value so as to maintain substantially optimum transfer of ink to the substrate during normal operating conditions.

ILLUSTRATIVE PARAMETERS FOR THE PREFERRED CIRCUIT

The following are the preferred parameters for the circuit illustrated in FIGS. 1*a* and 1*b* which circuit has been built and successfully operated. (All resistors are one-half watt with a precision of plus or minus 5 percent unless otherwise specified. All capacitor values are given in microfarads with a rating of 100 volts unless otherwise specified.)

C18, 0.00047 (10 kilovolts); C17, 0.00047 (10 kilovolts); R10, 22 ohms (2 watts); C7, 10 (250 volts); C20, 10 (250 volts); R48, 1 megohm; D5, D33, D22each type 1N2071; R1, 2 ohms (12 watts); C1, 1,000 (50 volts); R3, 22 kilohms; R4, 10 kilohms; R6, 10 kilohms; R9, 15 kilohms; D1, D2—each type MDA 970-2; C4, 20 (50 volts); R7, 47 ohms; C3, 0.1; P1, zero to 1 megohm; D3, type 1N459; C6, 0.1; C5, 0.22; R2, 10 ohms (2 watts); C2, 1,000 (50 volts); Q1, type C6A; R5 220 ohms; C24, 0.001; R12, 4.7 kilohms (1 watt); D8, type 1N645; D9, type 1N34A; R19, 1.8 kilohms (1 watt); Q6, type 2N3055; Q5, type 2N2102;Q2, type 2N699; R13, 15 kilohms; kilohms; D10, type 1N751A; R14, 47 kilohms; D4, type 1N645; C9, 0.05 (50 volts); C10, 50 (50 volts); Q4, type 2N1893; D6, type 1N4156; Q7, type 2N3645; D7, type 1N459; R16, 100 kilohms; R15, 15 kilohms; C8, 220 picofarads (1,000 volts); R11, 15 kilohms; Q8, type C6F; Q12, type 2N2646; R22, 47 ohms; R8, 47 kilohms; N10, type MB-216; R18, 1.8 kilohms (2 watts); R40, 10 kilohms; R25, 22 ohms (10 percent); C13, 50 (25 volts); P9 zero to 3 kilohms; Q20, type 2N4221; R50, 10 megohns; D26, type 1N645; R51, 10 kilohms (1 watt); C23, 1 (35 volts); D27, type 1N459; Q17, type 2N4249; Q3, type 2N4249; R23, 220 kilohms, C22, 10 (50 volts); R41, 10 kilohms; C19, 0.22; D20, type 1N4001; R43, 1 megohm; D19, type 1N4156; R42, 12 kilohms; R21, 100 kilohms; Q19, type C6F; R44, 220 ohms; D31, type 1N645; P10, zero to 20 kilohms (one-quarter watt); 22 megohms; D24, type 1N3595; C21, 5; D25, type 1N459; R46, 10 kilohms; R45, 47 kilohms; R47, 4.7 megohms; Q18, type 2N38 59A; D21, type 1N3595; D29, type 1N3595; D30, type 1N748A; R52, 15 kilohms; R53, 4.7 kilohms (1 watt); D12, type 7715-6; D13, type 7715-6; Q9, type 2N3583; Q10, type 2N3440; D11, type 1N645; Q15, type 2N5322; R28, 47 kilohms (1 watt); C15, 0.05; R26, 56 kilohms; R17, 6.2 kilohms; C16, 0.05; R24, 56 kilohms; R20, 4.7 kilohms (1 watt); P2, zero to 5 kilohms; D15, type 7715-6; D14, type 7715-6; T3, E4-181; Q14, type 2N3583; Q13, type 2N3440; R27, 6.2 kilohms; P4, zero to 10 kilohms; C11, 0.05; D16, type 1N645; Q11, type 2N5322; C14, 0.00047, (10 kilovolts); P5, zero to 1 kilohm; R30, 1.8 megohm (2 watts, 1 percent); R31, 2 megohms (2 watts 1 percent); R32, 2 megohms (2 watts 1 percent); P7, zero to 100 kilohms; P6, zero to 3 kilohms; D18, type 7715-6; D17, type 7715-6; R33, 240 kilohms (2 watts 5 percent); R34, 240 kilohms (2 watts 5 percent); R35, 240 kilohms (2 watts 5 percent); R36, 240 kilohms (2 watts 5 percent); R37, 240 kilohms (2 watts 5 percent); R38, 240 kilohms (2 watts 5 percent); R39, 240 kilohms (2 watts 5 percent); Q16, type 5557.

I claim as my invention:

1. In a printing system, an electric circuit having an output for supplying an electric potential across an ink-receiving substrate for assisting in the transfer of ink to the substrate, said circuit comprising electrical energy supplying means for supplying said output electric potential, automatic control means controlling said electrical energy supply means and operable during normal operation for gradually increasing said output electric potential at a relatively gradual rate of increase, automatic sensing means for automatically sensing when the output electric potential reaches a limiting potential value substantially equal to the breakdown potential of the substrate and for signaling such limiting potential condition, and automatic setback means coupled to said sensing means and responsive to said limiting potential condition during normal operation for automatically reducing the output electric potential to a reduced magnitude which is less than said limiting potential value but which is of a magnitude to maintain transfer of ink to the substrate, said automatic control means being automatically operable to gradually increase the output electric potential from said reduced magnitude at the completion of each cycle of the automatic setback means during normal operation, and safety circuit means responsive to a severe fault at the substrate to substantially remove the electric output potential during a safety cycle and to resume operation with a minimum value of electric potential which is substantially less than said reduced magnitude, said automatic control means being operable after a safety cycle to increase the output electric potential at a relatively rapid rate substantially greater than the relatively gradual rate of increase during normal operation, and said automatic control means being operable in response to the output potential reaching the limiting potential value to resume normal operation in the absence of a further severe fault in the substrate.

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