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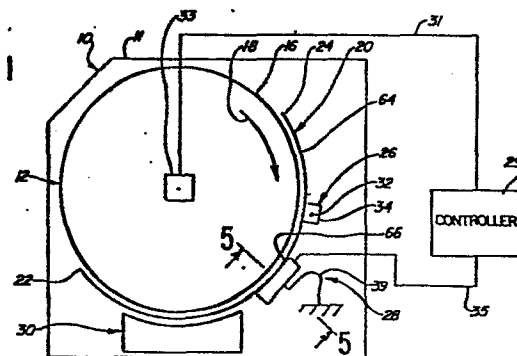
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54 **Method and apparatus for imaging electrophotographic member with heat energy.**

57 The electrostatic charge carried on the photoconductive coating surface of an electrophotographic member is discharged in certain areas by increasing the temperature thereof through application of heat energy. A thermal imaging head provides a plurality of point source heat elements linearly arranged across the width of the charged surface. Electrical current is passed through the resistive heat elements to dissipate energy which is transferred to the member.

FIG. 1



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This invention relates generally to imaging an electrophotographic member to produce a latent electrostatic image thereon that afterwards can be rendered visible by development using such as toner, and in particular relates to imaging the electrophotographic member by thermally exciting the photoconductive layer of the member.

Previously, formation of a latent electrostatic image on the surface over photoconductive surface layer of an electrophotographic member has involved the steps of corona charging the said surface to place an electrostatic charge on said surface and exposing the surface to illumination from an original image. Wherever light strikes the surface, the underlying photoconductor conducts away the carried electrostatic charge. In dark areas, where no light affects the plate, the electrostatic charge remains. Afterwards, the latent electrostatic image can be rendered visible by development with such as toner particles. The developed image then can be transferred to a receptor such as a sheet of paper and be fixed thereon, or the developed image can be fixed to the electrophotographic member. In the former case, the member is reusable to produce additional electrostatic and toned images. In the latter case, the member is used only once to form each image.

In a copier application of these electrophotographic principles, the charged member surface is exposed to a focused image of a well illuminated original document to form the latent electrostatic image. In a printer or writer application, the charged surface can be exposed by deflecting a beam of coherent light energy, such as from a laser, across the surface in a pattern of parallel lines with the light energy being modulated off and on to discharge selected areas of said surface.

In the printer application, the beam of light from the laser is modulated in accordance with such as digital data. This data is received from such as a memory device, directly from a scanner of an original document to be reproduced, or
5 from such as a word processing station producing text data. In any one of these or other cases, incremental areas of the charged surface are capable of being discharged or left charged as the beam is swept thereacross. The beam is swept across the charged surface by a rotating facet mirror or by
10 an oscillating raster mirror and beam modulation occurs acousto-optically. Present printers operating on these principles can image a letter sized page in a period of the order of seconds.

15 Such electrophotographic printers have been commercially accepted and have several common characteristics. The laser device producing the beam is inefficient; the electrical energy required to produce the beam is large compared to the light energy produced. Only a portion of the laser beam
20 energy is passed by the beam modulator to the surface of the member even when a maximum writing beam is desired. The optical path from the laser, through the modulator to the rotating or raster mirror and then to the electrophotographic member requires substantial enclosed cabinetry
25 space. A control system must be provided to synchronize beam modulation with the position of the beam along a scan line. Cooling must be provided to remove from the cabinet interior the wasted and used energy. In some printer applications used to make lithographic offset printing plates,
30 the cooling is supplied by running tap water across the laser while blowing air conditioned room air through the cabinet.

Prior electrophotographic members also have several common
35 characteristics. The members require charging the surface to several hundred volts with a corona device. This requires

a suitable high voltage supply, corona wire and insulation and shielding which requires cooling, space and adds weight to the printer.

- 5 Recently, more efficient electrophotographic members have become known. These members, disclosed and claimed in U.S. Patent 4,025,339 and U.S. Patent 4,269,919 operate with a surface potential of less than -50 volts which substantially reduces the power consumption, size and weight
- 10 of the charging apparatus. Further, this member can be charged and imaged in a period that is shorter than has been possible with previous electrophotographic members, increasing the rate at which the member can be imaged. The disclosed and claimed members also have a high photoelectric
- 15 gain, which requires less light energy to discharge the electrostatic charge carried thereon; thus, the laser system can be smaller, lighter and consume less power than prior systems.
- 20 Heretofore, only light energy was considered to operate the photoconductive coating of the electrophotographic member and discharge certain areas to effect the latent electrostatic image. The very names of the photoconductive coating and electrophotographic member indicated that they intended
- 25 to be operated upon with light energy. These names were ascribed because the active coatings and members were light sensitive and changed their insulator characteristics rapidly when exposed to light energy.
- 30 Theoretical descriptions of the photoconductive effect upon which these coatings and members operate have been based upon quantum physics principles. Under that theory, the light is described as individual photons or quanta or packets of energy, each having an energy level directly related to its
- 35 frequency or color. These photons are directed onto a charged

photoconductive coating. Photons at or above a certain energy level described by their frequency or color impringe upon an electron of the photoconductor, raise it to a conduction energy state and then that electron aids in discharging the electrostatic charge carried on the photoconductive surface. Photons below this certain level have insufficient energy to raise the electrons to the conduction energy state and therefore those areas of the coating at which these low energy photons strike remain charged. This theory is deeply ensconced and experimentally appears well founded. Under this theory and as a practical matter, the frequency or color of the light is selected to be above the certain energy level for effecting conducting electrons.

There is little thermal excitation of the electrophotographic member using the photoconductive effect. Most of the energy from the light is used to effect conducting electrons. Light of a frequency or color below this certain energy level is not used to effect imaging because it cannot discharge the electrostatic charge.

Increasing the temperature of the electrophotographic member has been anathema to electrostatic imaging. Such a member has a much faster electrostatic charge dark decay rate at a higher temperature, reducing the time available in which to perform imaging and toning. Maintaining the member at room temperatures results in dark decay rates that allow sufficient time for practical imaging and toning techniques.

Recent nonimpact paper printing techniques have employed heat to form discernible characters. The techniques have developed along two lines. First, specially coated paper can be moved past a linear array of point source heat elements, each producing thermal energy resistively from electricity passed therethrough. This heat energy is conducted to an incremental area of the coated paper. The applied heat

raises the temperature of the coating in that area sufficiently for the coating to change chemically and exhibit a desired color different from the unheated areas. Heating adjacent incremental areas of the paper forms desired
5 characters thereon.

The second technique involves moving plain paper past a writing head having a linear array of point source heat elements and an interposed ribbon. Again, the heat sources
10 each produce thermal energy or heat resistively, but the heat is applied to the ribbon and not the paper. Incremental areas of the ribbon are heated to a temperature sufficient to melt the colored wax carried thereon, which then is accepted by and solidifies on the plain paper to form a
15 discernible dot. Formation of adjacent dots forms the desired character.

The advantages of these thermal printers include the reduced size of the writing head and controls. The writing head is a
20 thin strip carrying the linear array of heat elements. Power requirements are relatively efficient; writing power is applied only to the spots to be imaged. Character generation control is provided by low power, small and lightweight integrated circuits. The main disadvantages of thermal printing are the time required to heat each incremental area to
25 the required temperature and the need for special coated paper of wax ribbons.

It is readily apparent that electrophotography and thermal
30 printing operate on entirely different principles. Electrophotography operates on quantum physics principles while thermal printing operates on thermal chemistry of simple melting of a solid. Thus, while electrophotography and thermal writing require learning and reasoning to effect
35 commercially acceptable products, the principles lead down different and diverging paths.

Several different types or forms of energy have been and will be discussed herein. Generally, energy is described to be in one of two forms: potential and kinetic.

- 5 Potential energy is energy that is stored. Examples of stored energy are: the water behind a dam that later is pulled by gravity through the turbines to produce electrical energy; the chemical energy stored in a battery for later release to produce electrical energy; the voltage potential
10 of the electrostatic charge induced on the surface of a photoconductive coating and the heat or thermal energy of a high temperature body used to store sun's radiated energy in a solar heating systems.
- 15 Kinetic energy is energy that exists in moving bodies. Examples of kinetic energy are: a moving car; the water from behind the dam moving through the turbines; the electricity moving through a wire; photons of light moving through space a certain color; electrons revolving around
20 their nucleus and molecules in a gas or solid moving or vibrating and indicating a certain temperature, as in the case of the solar heating system body.

According, the invention provides a method of discharging
25 in darkness portions of an electrostatic charge carried on the top surface of the photoconductive layer of an electrophotographic member, the photoconductive layer being capable of accepting a charge and retaining the charge to effect on said surface certain discharged and other charged incre-
30 mental image areas forming a latent electrostatic image, characterized in that said discharging being effected by applying heat energy to the charge carrying surface at localized areas at levels below the energy level required to obtain the photoconductive effect in said member to at
35 least a portion of the upper thickness of said member under said certain incremental areas.

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Further, the invention provides an apparatus for imaging an electrophotographic member to produce thereon a latent electrostatic image, the electrophotographic member including a substrate, a conductive layer carried on the substrate and a photoconductive layer carried on the conductive layer, the electrophotographic member having a top surface over said photoconductive layer opposite said conductive layer and being capable of accepting a charge and retaining the charge for a sufficient period to enable toning thereof, the produced latent electrostatic image thereafter being capable of being toned to render same visible, the apparatus characterized by a light proof enclosure surrounding the electrophotographic member to maintain the member in darkness; charging means internal said enclosure for inducing a uniform electrostatic charge on said surface over the photoconductive layer; and discharge means internal of said enclosure for discharging portions of said uniform electrostatic charge to effect on said surface certain discharged and other charged incremental image areas forming said latent electrostatic image, said discharge means including an energy source and transmitter for increasing the heat energy of at least a portion of the upper thickness of said member under said certain incremental image areas sufficiently to discharge at least a portion of the electrostatic charge carried over each certain area.

The preferred embodiments of this invention now will be described, by way of example, with reference to the drawings accompanying this specification in which:

Fig. 1 is a diagram of an electrophotographic apparatus operating on the thermal imaging principles of the invention;

Fig. 2 is a plan view of a portion of an imaging head front face used to effect the invention;

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Fig. 3 is a plan view of a portion of a top surface of the electrophotographic member used with the invention, illustrating connected portions a diagram form;

Fig. 4 respectively are graphs taken along time A, B, illustrating the relative occurrence of and C current flow through a heat element, the discharge of the electrostatic charge carried by the electrophotographic member at that element, and the registration of incremental image areas with that heat element; and

Fig. 5 is a partial sectional view of the imaging head and electrophotographic member of Fig. 1 taken along the line 5-5 and in the direction indicated by the arrows.

The invention best will be understood by considering that certain areas of the charged surface of a photoconductive coating of an electrophotographic member will be discharged upon the application of energy thereto to increase the temperature of the underlying photoconductive coating. The applied energy is believed to be in three forms, comprising mainly conducted heat from higher temperature writing head heat elements to the member, a lesser quantity of radiant energy occurring in the far infrared at approximately 8 microns in wavelength and a minimal quantity of heat transferred by convection. The exact forms and the relative quantities of energy transferred are not precisely known and can be otherwise than described while remaining within the scope of the invention. This energy, including the radiated energy, is at energy levels below the photoconductive sensitivity level of the member. Accordingly, the

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traditionally described photoconductive effect is not used in imaging with the present invention.

Instead, increasing the heat energy content or temperature of the photoconductive coating, it is postulated, frees trapped electrons from the structure of the coating and also produces phonons or quanta of energy. The freed electrons are at conductive energy levels and discharge the overlying electrostatic charge.

The temperature of the photoconductive coating at which this "thermoconductive" effective occurs is substantially less than is presently used for thermal writing on paper; thus less energy need be produced resistively in the thermal elements to obtain the discharge effect. The electrophotographic member used with the preferred embodiment of the herein invention has fine resolution across its surface area that allows small area thermal elements to be used, and results in a finer latent electrostatic image than was previously available. The smaller area thermal elements reduce the thermal inertia that could otherwise slow the temperature rise and fall times. The lower imaging temperature also decreases the rise and fall times.

In figure 1, an electrophotographic apparatus incorporating the invention is indicated generally by the reference numeral 10. The apparatus 10 comprises, interior of light proof cabinet 11, a cylindrical drum 12 arranged for rotation around its longitudinal axis 14 and having a circumferential surface 16. In this embodiment, drum 12 rotates in the direction indicated by arrow 18 in a continuous manner.

An electrophotographic member 20 is carried engaged on the surface 16 of drum 12 for revolution therewith. The member 20 is illustrated spaced from surface 16 only to readily identify the member 20; member 20 is then compared to the diameter of the drum and would not in this view appear if

drawn engaged on the drum surface. Member 20 is generally rectangular and, as carried by drum 12, has a leading edge 22 and a trailing edge 24. Alternatively, member 20 can be formed directly on surface 16 so that drum 12 and member 20 are unitary.

Apparatus 10 further comprises a charging station 26, a thermal imaging head 28 and a development or toning station 30 arranged for the member leading edge 22 to pass by each named sub-assembly in the order stated. Charging station 26 includes a corona wire 32 extending the width of member 20 inside reflecting shield 34 and longitudinally of the drum. Corona wire 32 is closely spaced from member 20 to induce a uniform electrostatic charge thereon in accordance with known electrophotographic principles. Thermal imaging head 28 effects imaging of member 20 by discharge of certain areas and leaving charged other areas of the member 20 resulting in a desired, latent electrostatic image. Head 28 is biased for engagement against member 20 by a spring 39 and extends across the width of member 20 longitudinally of the drum. Toning station 30 develops the latent image to render same visible using known toning principles.

A controller 29 receives information concerning drum rotation over lines 31 from rotation transducer 33. Timed signals for producing the latent image are passed over lines 35 to imaging head 28 from controller 29.

Referring to figures 2 and 5, thermal imaging head 28 comprises a base 34 having a front face 36. A plurality of thermal writing heat elements R1, R2, R3, R4 and R5 are desposited on face 36 by using such as photographic techniques to obtain precisely dimensioned, placed and geometrically shaped elements. The heat elements are arranged to form a linear array 37. These heat elements are illustrated as layer 38 in figure 5. Leads 40, 42, 44 and 46 extend

from ends of each heat element to switches SWV1 and SWV2 connecting the heat elements to voltage +V and to switches SWG1 and SWG2 to electrical ground. The positive voltage +V appears on lead 48 while electrical ground appears on
5 lead 50. The leads 40', 42', 44' and 46' diagrammatically represent continuation of the leads of the integrated circuits performing the functions represented by switches SWV1, SWV2, SWG1 and SWG2. A covering 52 of abrasion resistant, electrical insulating and energy transferring
10 material is applied over the front face 36 of base 34 and the heat elements and leads for purposes to be discussed presently.

Member 20, in the preferred embodiment, is the member
15 disclosed and claimed in U. S. Patent 4,269,919. Member 20, figure 5, comprises a substrate 54 carrying an electrically conductive ohmic layer 56 and a photoconductive coating 58. An interposed bonding layer 60 is applied to the substrate 54 ensures bonding of the ohmic layer 56 to said substrate 54.
20 A barrier layer 62 is formed over the photoconductive layer 58.

Coating 58 is a microcrystalline deposit of a wholly inorganic material, in the preferred form comprising cadmium
25 sulfide, of almost perfect stoichiometry, either with or without small amounts of dopant. Substrate 54 can be a thin, clear, flexible polyester sheet and the conductive layer can be such as indium-tin oxide. The layer 58 has microcrystals that are generally uniformly oriented vertically relative to
30 the surface of the substrate, and have hexagonal morphology and great uniformity. Barrier layer 62 formed of an oxide provides surface anisotropy and deep electrical traps.

In figure 3, the top surface 64 of member 20 can be thought
35 of as a plurality of incremental image areas IA1-IA15 divided by intersecting lines 68. In actuality there are

no lines 68 printed or scribed on top surface 64 of member 20, the lines being used only for description of the preferred embodiment. Each image area, such as IA7, is the area over which one heat element, such as R2 of figure 2, will operate when the member 20 is moved past the imaging head 28. Thus, heat element R2 will seriatim operate over image areas IA2, IA7 and IA12 as the member 20 moves in the direction indicated by the arrow 69. Likewise, the other heat elements will operate over the other image areas. Heat element R1 will operate over areas IA1, IA6 und IA11. Heat element R3 will operate over areas IA3, IA8 and IA13. Heat element R4 will operate over areas IA4, IA9 and IA14. Heat element R5 will operate over areas IA5, IA10 and IA15.

15 In the preferred embodiment, member 20 is large enough to provide a top surface 64 of image areas for imaging a letter sized document. Member 20 thus is slightly larger than 8-1/2'' by 11''. Imaging head 28 provides heat elements 20 at 300 elements to the inch so that there is a line of approximately 2560 heat elements or more. The additional heat elements are located at the ends of the linear array to ensure that the edges of the member are fully imaged.

25 The Length L of the heat elements corresponds closely with the length l of the image areas. The width W of the heat elements is much less than the width w of the image areas. The difference in widths results from the relative movement of the member 20 and imaging head 28, the head elements per- 30 forming the imaging of the areas over time as the member 20 moves therepast. Thus, a relatively narrow heat element can image a much wider image area.

It will be understood that the heat elements and image 35 areas illustrated in the drawing are indicative of the remaining not illustrated heat elements and image areas so

that the totality thereof need not be illustrated. The exact length and widths, L, l, W and w can be selected to effect a desired resolution.

5 In the operation of apparatus 10, in the darkness provided by cabinet 11, the leading edge 22 first passes by charging station 26. The corona wire 32 operates to induce a uniform electrostatic charge over the surface 64 of the member 20. Drum 12 then moves member 20 so
10 that leading edge 22 next passes by imaging head 28. The heat elements thereof discharge certain areas and leave charged other areas to form the latent electrostatic image. Member 20 last is moved, leading edge 22 first, past toning station 30 where the latent electro-
15 static image is toned and rendered visible. Thereafter, the toned image can be fused to member 20 by heat means (not shown) or the toned image can be transferred to a receptor (not shown) such as paper at a transfer station (not shown). These are well known operations
20 in electrophotography. The charging, imaging and toning of member 20, or the image produced thereon, continues over the length of member 20 until trailing edge 24 passes by the described stations and head. Thereafter, the imaging process can repeat by another
25 resolution of drum 12.

When leading edge 22 passes by imaging head 28, the member surface 64 engages against the outside face 66 of the head. Covering 52 provides abrasion resistance
30 to the member sliding thereagainst and electrically insulates the head 28 from the electrostatic charge carried on member 20, maintaining the charge at the level induced at the charging station 26. This is expect for the charge lost due to the dark decay rate
35 of the member. The linear array 37 of heat elements come into registration with the member 20 as it moves therepast.

Controller 29 receives from transducer 33 signals indicative of the rotation of drum 12 and, thereby, movement of member 20. Controller 29 produces on lines 35 timed electrical switch control signals in response to the drum rotation signals and in response to data supplied to the controller representing the latent image to be formed. In response to the timed switch control signals, the switches such as SWV1, SWV2, SWG1 and SWG2 of figure 2 will be opened or closed or will maintain their condition.

For example, when the leading edge 70 of image area IA7 approaches alignment with edge 72 of element R2, switches SWV1 and SWG1 can be closed leaving switches SWV2 and SWG2 open. Electrical current then flow from constant voltage source +V on lead 48 through leads 40' and 40 to heat element R2, therethrough to leads 42 and 42' and lead 50 to ground. Heat element R2 is made of a resistive material and exhibits a determined resistance. Electrical energy is dissipated into element R2 when current flows therethrough and appears in the form of heat or thermal energy and low level radiant energy in the infrared region. This begins the discharge of the electrostatic charge carried over area IA7.

Referring also to figure 5, the base 34 is formed of insulating material and therefore, the heat introduced into element R2 preferentially passes through covering 52 to the member 20 across area IA7. This heat energy first is absorbed by barrier layer 62, then coating 58, later ohmic layer 56 and lastly substrate 54. Electrical current continues to flow through element R2 increasing the heat energy and temperature thereof, and of the upper portions of the thickness of member 20, i.e. the barrier layer and coating. The imaging head and member under area IA7 both are at approximately ambient room

temperature of 20°C before current flow through the element R2. It has been determined that increasing the temperature of the upper portions of member 20, i.e. the barrier layer 62 and coating 58 or portions thereof, to no more than 100°C completely discharges the electrostatic charge carried thereon. This temperature is achieved in barrier layer 62 and coating 58 by passing sufficient current through element R2 for a sufficient period, the current being large enough to effect or obtain sharp edges to the incremental area IA7 imaged on member surface 64.

Once this complete discharge temperature is reached, the electrical current flow through element R2 is maintained at some level to achieve the discharge temperature across the entire field of incremental area IA7. This is while the member and imaging head are moved relative to one another.

After the member and head have moved relative to one another a sufficient distance to obtain an incremental image area of desired size, i.e. when trailing edge 74 of area IA7 approaches edge 76 of element R2, the electrical current flow through heat element R2 is interrupted. This occurs by controller 29 opening at least one of switches SWV1 and SWG1 in response to drum rotation signals from transducer 33. No additional heat energy is introduced into element R2 and the heat energy existing in element R2 and head 28 continues to flow into member 20 where it is dissipated into the lower temperature ohmic layer 56 and substrate 54. The dissipation of heat energy into substrate 54 reduces the temperature of barrier layer 62 and coating 58 so that the next following incremental image area IA12 of surface 64 can retain the electrostatic charge thereon. The heat dissipation qualities of head 28

and member 20 are selected to obtain a sharp edge of the incremental image area IA7 when current flow ceases through heat element R2.

- 5 Thus a certain incremental image area IA7 of surface 64 can be discharged while other image areas IA2 and IA12, previous and following, remain charged. This imaging procedure can be effected using any heat element to discharge the charge carried on surface 64 in any incremental
10 image area in a like manner.

The energy transferred in the example from heat element R2 to member 20 to discharge area IA7 is believed to be in three forms: conducted heat, radiated far-infrared
15 and convected heat. The conducted heat transfer is believed to occur by the heat or thermal energy in element R2 thermally exciting the covering 52, which engages with member 20, and which in turn thermally excited the member 20. This conducted heat flows by reason of temperature
20 differential from element R2 to substrate 54 and is believed to comprise the major portion of energy transfer. The far-infrared transfer of energy is believed to occur at wavelengths of approximately 8 microns or longer. This radiated energy is produced at element R2
25 and is transmitted therefrom through covering 52 to barrier layer 62 and coating 58 where it is absorbed. The absorption converts the radiated energy to heat or thermal energy in the material of barrier layer 62 and coating 58. Convection of heat energy from head 28 to
30 member 20 can occur at any nonengaging voids therebetween by heating an interposed fluid or gas. This form of heat transfer in the given example is believed negligible. Alternatively, it can be made a major method of energy transfer by disengaging the head and
35 member and interposing a transfer fluid or gas.

The energy transferred from head 28 to member 20 is kinetic energy. The conducted and convected energy manifests itself as movement of the molecules and atoms of the structures of the described bodies. In the solid covering, barrier layer and coating, this motion is a vibration of the molecules and atoms of the crystal lattices in which they occur. At higher energy contents, the vibrations and apparent temperatures are higher. In any gas trapped between the head and member the kinetic energy manifests itself in more active movement of the gas molecules. The kinetic energy of the radiant energy manifests itself by the wavelength at which the photons are traveling.

In any event, the energy transferred from head 28 to member 20 is believed to be at levels below those required to obtain the photoconductive effect in layer 62 and coating 58. The postulated theory to explain the achieved results concerns the heat or thermal excitation of the barrier layer 62 and coating 58 materials to release trapped electrons from the crystal lattice of the materials and emit quanta of energy or packets called phonons. The released or freed electrons are at conductive energy levels and operate to discharge the electrostatic charge thereof.

The postulated theory or theories expressed herein are to assist in a possible understanding of the invention and are not to limit the invention. The imaging of the electrophotographic member occurs and is operative irrespective of the theory stated.

Referring to figure 2, passing electrical through element R3 occurs by closing switch SWV2 and SWG1. Passing current through element R2 occurs by closing switch

SWV2 and SWG2. Other schemes for passing current through heat elements are known, are commercially available and can be used in the image head 28.

- 5 Figures 4A, 4B and 4C graphically illustrate the relative timing concerning current flow through a heat element, electrostatic discharge and production or alignment of image areas. The small vertical ticks upstanding from the time line of each graph indicate equal time inter-
- 10 vals occurring after an initial instance t . Because the graphs illustrate timing principles and not absolute values of current flow and electrostatic change, the ordinates of figures 4A and 4B are not marked by exact quantities, which will be understood by those of ordinary
- 15 skill in this field. Rather the ordinate of figure 4A is marked at some value of current I_D and the ordinate of figure 4B is marked at some value of voltage V_c , which can be negative or positive. The ordinate of figure 4C is unitless and is unmarked. It will be understood that
- 20 the wave shapes illustrated are idealized for explanation purposes.

At time t_0 , the heat element current for a single heat element is zero and the electrostatic charge on the

25 correspondingly aligned or registered image area I_{An-1} on surface 64 is V_c volts, the maximum that it can be. No discharge of the carried charge occurs.

At time T_1 , current I_D starts flowing through the heat

30 element and begins to reduce the charge voltage from V_c to zero volts through operation of the previously described thermal or heat imaging operation. Complete discharge occurs by a short time later. This discharge results in the leading edge or boundary 78 of image

35 area I_{An} . At time 4_4 , the current ceases flowing through the heat element and the charge voltage begins to

increase from zero volts to V_c upon interruption of the thermal imaging procedure. This results in a trailing edge or boundary 80 of image area I_{An} and the leading edge or boundary 80 of image area I_{An+1} . Boundaries 78 and 80 of area I_{An} in figure 4C correspond with leading and trailing edges 70 and 74 of area I_{A7} in figure 3.

It will be remembered that the member is moved relative to the head at a constant, continuous rate so that image area move past the heat element at equal times. Note that there is a slight time offset from the points at which current starts and ceases flowing through the heat element to the location of image areas. This results from the temperature rise and fall times in the Member 20. Alternatively, the drum can be rotated in steps with such as a stepping motor to move the heat elements across the image areas.

Image area I_{An} then is completely discharged and two subsequent areas I_{An+1} and I_{An+2} travel past the heat element while remaining charged to voltage V_c . Areas I_{An+1} and I_{An+2} remain charged as a result of no current flow through the aligned heat element.

From times t_{10} to t_{13} current I_D again flows through the heat element discharging image area I_{An+3} . From times t_{13} to t_{16} current ceases to flow in the heat element allowing image area I_{An+4} to remain charged.

The current I_D again flows from time t_{16} to t_{22} discharging two sequential image areas I_{An+5} and I_{An+6} . The dashed line 82 indicates where current normally would cease to discharge a single image area and the dashed line 84 indicates the charge voltage occurring at the trailing edge of a discharged image area.

Alternatively, instead of completely discharging the charge V_c over an incremental image area, the charge can be partially discharged to obtain a gray scale in the latent and toned image. This is indicated in image area IAn by passing a partial current I_p through the heat element to obtain a partial discharge of the carried charge to V_p . The procedure for obtaining this partial discharge is heating the upper portions or thickness, i.e. barrier layer and coating or portions thereof, of the member to intermediate temperatures between ambient and 100°C .

The preferred electrophotographic member exhibits the ability to accept an almost constant surface voltage electrostatic charge from well below -20°C to just over $+20^\circ\text{C}$, or approximately room ambient temperature. Above approximately $+25^\circ\text{C}$ the surface voltage that the preferred member will accept decreases slowly by about 10% at $+40^\circ\text{C}$ and more rapidly thereafter. This or a like phenomenon is believed also applicable to other like electrophotographic members with an increase in temperature.

Another ability exhibited by the preferred member is its long dark decay rate, the member holding its charge for many seconds. It is postulated in retrospect that the discharge imaging using heat of the invention can be described as an increased dark decay rate exhibited by the member at increased temperature, and by the member's reduced ability to accept charge at elevated temperatures.

Imaging with the thermal imaging head of the invention has several advantages over imaging with light energy. First, the thermal imaging head required little space while laser imagers require large volumes in which to

sweep the light energy beams and photocopiers require large volumes in which to project the document images. Second, the thermal imaging head applies almost all of the resistively dissipated energy into the electrophotographic member to effect imaging. Laser imagers and photocopiers apply only small amounts of energy to the electrophotographic member relative to the electrical energy required to produce the intermediate light energy. Because of this energy transfer efficiency, a smaller and cooler power supply is used with the thermal imaging head than in a laser imager or a photocopier.

It has been expressed herein that raising the temperature of the upper portion or thickness of the member to +100°C effects complete discharge of the charge carried thereon. This temperature is not an absolute value, nor is it the minimum to which the member must be raised to effect discharge. It is believed that complete discharge can be effected quickly at a temperature of 80-90°C. Further, it is postulated that the degree of discharge depends upon the time integrated absorption of energy by the electrophotographic member rather than a specific temperature. This is irrespective of the means or method of energy transfer from the thermal imaging head. Therefore, applying a small quantity of energy to the member for a long period obtains the same discharge as applying a large quantity of energy for a short period.

Additionally, applying a small quantity of energy in a short period obtains a partial discharge, which contributes to effective a gray scale on the member.

This low imaging temperature is advantageous. Present thermal writing devices heat their resistive elements to approximately +300°C over such as a 2 millisecond period, i.e. electrical energy is dissipated as heat in a resistive

element to raise the element's temperature from 0°C to 300°C in a 2 millisecond period. Thereafter, the element is allowed to cool for an additional 2 milliseconds before the next cycle starts. This high +300°C temperature is required to effect the thermochemical reaction rendering the image visible. The present invention is advantageous because it operates at a substantially lower temperature.

A benefit of the lower operating temperature is shorter rise and fall times for the heat elements to achieve the desired discharge temperature. In turn, the shorter thermal rise and fall times enable continuous movement of the member relative to the imaging head, or vice versa if desired, while still obtaining sharp edges to the image areas. Present thermal writing devices operate by stepping the thermally sensitive member relative to the thermal head. The thermally sensitive member then is stationary during the millisecond thermal rise and fall times. Movement could cause incomplete or improper thermochemical reaction. Reducing the heat element temperature to no more than 100°C then greatly facilitates imaging on-the-fly or continuously.

Additionally, by having to increase temperature to no more than 100°C, more imaging pulses can be produced in the same time that present thermal writes produce one 300°C heat pulse, i.e. milliseconds. This results in the thermal imaging of the invention being able to occur more rapidly than the thermal printing of the present.

The power or rate of energy transfer to image an area of surface 64 corresponding to an A4 sized sheet of paper is approximately one (1) watt and is calculated as follows:

Assume:

A. Thickness of barrier layer 62 and photoconductive coating 58:

(1) $d = 30 \times 10^{-6} \text{ cm}$

5

B. Density of the barrier layer and photoconductive coating material:

(2) $p \approx 4.82 \text{ gm/cm}^3$

10 (3) C. Area to be imaged:

$A \approx 603 \text{ cm}^2$

Then

(4) Mass $M = p \times d \times A = 8.7 \times 10^{-2} \text{ gm}$

15

Assume:

D. Specific heat of the barrier layer and photoconductive coating material:

(5) $c = 0.088 \text{ cal./(gm } ^\circ\text{C)}$

20

E. The increase in temperature:

(6) $t = 10^2 \text{ degrees C}$

Then:

25 Energy $Q = M \times c \times t = 0.7 \text{ cal} = 3.2 \text{ watt sec}$
 $= 3.2 \text{ Joules}$

Assume:

(8) F. image one page in a time of three (3) seconds

30

$T = 3 \text{ seconds}$

Then:

(9) Power $= \frac{Q}{T} = 1 \text{ watt per page}$

35 This compares with several hundred watts per page required by conventional thermal printers.

CLAIMS:

1. A method of imaging an electrophotographic member to produce thereon a latent electrostatic image, the electro-
5 photographic member including a substrate, a conductive layer carried on the substrate and a photoconductive layer carried on the conductive layer, the electrophotographic member having a top surface over said photoconductive layer opposite said conductive layer and being capable of
10 accepting a charge and retaining the charge for a sufficient period to enable toning thereof, the produced latent electrostatic image thereafter being capable of being toned to render same visible, said method characterized by:
- 15 A. charging in darkness the electrophotographic member to induce a uniform electrostatic charge on said top surface over the photoconductive layer;
- 20 B. discharging in darkness portions of said uniform electrostatic charge to effect on said surface certain discharged and other charged incremental image areas forming said latent electrostatic image, said discharging including increasing the
25 heat energy of at least a portion of the upper thickness of said member under said certain incremental image areas sufficiently to discharge at least a portion of the electrostatic charge carried over each certain area.
- 30 2. The method according to claim 1 characterized in that said increasing the heat energy includes applying a determined quantity of energy in a certain period to said member.

35

3. The method according to claim 2 characterized in that said applying includes dissipating electrical energy in a heat element and transferring said dissipated energy to said member.
- 5
4. The method according to claim 3 characterized in that said transferring includes at least one of conducting, radiating and convecting energy from said heat element to said member.
- 10
5. The method according to claim 2 characterized in that said applying includes at least one of conducting, radiating and convecting energy to said member from an energy source.
- 15
6. The method according to any one of claims 1 to 5 characterized in that said member is moved while effecting said discharging.
- 20
7. The method according to any one of claims 1 to 5 characterized in that said member is moved continuously while effecting said discharging.
8. The method according to any one of claims 1 to 7
- 25
- characterized in that said step of discharging includes partially discharging the electrostatic charge of the certain image areas to produce a gray scale.
9. The method according to any one of claims 1 to 8
- 30
- characterized in that said member is maintained substantially at room temperature except at those member portions under said certain image areas.
10. The method according to any one of claims 1 to 9
- 35
- characterized in that the step of increasing the heat energy includes raising the temperature of said at least

a portion of the upper thickness of said member under said certain incremental image areas to less than 100°C.

11. The method according to any one of claims 1 to 10
5 characterized by providing an imaging head and engaging said imaging head with said surface.

12. The method according to any one of claims 1 to 11
10 characterized in that increasing the heat energy includes applying a time integrated quantity of energy to said member.

13. The method according to any one of claims 1 to 12
15 characterized by the steps of providing a charging station, an imaging head and a toning station and the further step of toning said latent electrostatic image to obtain said
toned image on said member by applying toner particles to said surface to render visible one of said certain
discharged image areas and said other charged image areas
20 and to leave clear the other of said certain discharged image areas and said other charged image areas.

14. A method of imaging to produce a toned image on an electrophotographic member, the member including a sub-
25 strate, a conductive ohmic layer carried on the substrate, a photoconductive coating carried on the ohmic layer and a barrier layer carried on the photoconductive coating, said barrier layer having a top surface opposite said coating, said coating being formed of cadmium sulfide of
30 near perfect stoichiometry exclusive of doping, and being microcrystalline of closely packed, vertically arranged relative to the substrate, hexagonal crystals of the same length as the thickness of the coating, the barrier layer being chemically similar to the coating and including
35 oxygen in a combined form, the barrier layer providing electrical anisotropy and surface resolution for imaging

of 1000 lines per millimeter and better and being capable of accepting rapid electrostatic charge and retaining the charge to a degree enabling toning, the method including the steps of enclosing the member in darkness; cyclically

5 moving the member surface sequentially past a charging station, an imaging station and a toning station; charging said member at said charging station to induce upon said surface a uniform negative electrostatic charge having a surface potential of the order of less than -50 volts,

10 said charging including closely spacing said surface from a corona wire extending over said surface width and applying of the order of thousands of volts to said corona wire; discharging portions of said electrostatic charge on said member to effect on said surface a latent electro-

15 static image of certain discharged incremental image areas and other charged incremental image areas and toning said latent electrostatic image by applying toner particles to said member surface at the toning station to render visible one of said certain discharged image areas and said other

20 charged image areas and to leave clear the other of said certain discharged image areas and said other charged image areas; characterized by providing an imaging head at the imaging station and engaging an outside face of said head against said charged surface, dissipating timed quantities

25 of electrical energy in resistive heat elements that are under said outside face and transferring the dissipated energy to said barrier layer and coating under said certain incremental image areas for increasing the heat energy thereof sufficiently to discharge said electrostatic charge

30 thereover.

15. The method according to claim 14 characterized in that said transferring the dissipated energy includes at least one of conducting, radiating and convecting energy from

35 said heat elements to said member.

16. The method according to claims 14 or 15 characterized in that the member surface is continuously moved.

17. The method according to any one of claims 14 to 16
5 characterized in that the member is maintained at substantially room temperature.

18. The method according to any one of claims 14 to 17 in
10 which increasing the heat energy includes raising the temperature of said at least a portion of the upper thickness of said member under said certain incremental image areas to less than 100°C.

19. An apparatus for imaging an electrophotographic member
15 to produce thereon a latent electrostatic image, the electrophotographic member including a substrate, a conductive layer carried on the substrate and a photoconductive layer carried on the conductive layer, the electrophotographic member having a top surface over said photoconductive layer
20 opposite said conductive layer and being capable of accepting a charge and retaining the charge for a sufficient period to enable toning thereof, the produced latent electrostatic image thereafter being capable of being toned to render same visible, the apparatus characterized by:

25

A. a light proof enclosure surrounding the electrophotographic member to maintain the member in darkness;

30

B. charging means internal of said enclosure for inducing a uniform electrostatic charge on said surface over the photoconductive layer; and

35

C. discharge means internal of said enclosure for discharging portions of said uniform electrostatic charge to effect on said surface certain

discharged and other charged incremental image areas forming said latent electrostatic image, said discharge means including an energy source and transmitter for increasing the heat energy of a least a portion of the upper thickness of said member under said certain incremental image areas sufficiently to discharge at least a portion of the electrostatic charge carried over each certain area.

10

20. The apparatus according to claim 19 characterized in that said energy source and transmitter is an imaging head capable of applying a determined quantity of energy in a certain period to said member.

15

21. The apparatus according to claim 19 characterized in that said energy source and transmitter is an imaging head capable of applying a determined quantity of energy in a certain period to said member, said imaging head having heat elements in which electrical energy can be dissipated.

20

22. The apparatus according to claim 19 characterized in that said energy source and transmitter is an imaging head capable of applying a determined quantity of energy in a certain period to said member, said imaging head having heat elements in which electrical energy can be dissipated, said imaging head having an outside face engaged with said member surface.

25

30 23. The apparatus according to claim 19 characterized in that said energy source and transmitter is an imaging head capable of applying a determined quantity of energy in a certain period to said member said imaging head being capable of raising the temperature of said at least a portion of the upper thickness of said member under said certain incremental image areas to less than 100°C.

35

24. The apparatus according to any one of claims 19 to 23 characterized in that a cooling device is provided to maintain the said member substantially at room temperature.

5 25. The apparatus according to any one of claims 19 to 24 characterized by toning means for toning said latent electrostatic image to obtain a toned image on said member by applying toner particles to said surface to render visible
10 one of said certain discharged image areas and said other charged image areas and to leave clear the other of said certain discharged image areas and said other charged image areas.

26. An apparatus for imaging to produce a toned image on a
15 electrophotographic member, the member including a substrate, a conductive ohmic layer carried on the substrate, a photoconductive coating carried on the ohmic layer and a barrier layer carried on the photoconductive coating, said barrier layer having a top surface opposite said
20 coating, said coating being formed of cadmium sulfide of near perfect stoichiometry exclusive of doping, and being microcrystalline of closely packed, vertically arranged relative to the substrate, hexagonal crystals of the same length as the thickness of the coatings, the barrier
25 layer being chemically similar to the coating and including oxygen in a combined form, the barrier layer providing electrical anisotropy and surface resolution for imaging of 1000 lines per millimeter and better and being capable of accepting rapid electrostatic charge and
30 retaining the charge to a degree enabling toning, the apparatus characterized by:

A. an enclosure that surrounds said member and that maintains said member in darkness and
35 at room temperature;

- B. charging means, an imaging head and toning means interior of said enclosure;
- 5 C. drive means for cyclically moving the member sequentially past said charging station, imaging head and toning system;
- 10 D. said charging means for inducing a uniform negative electrostatic charge upon said surface to a surface potential of the order of less than -50 volts, said charging means including a corona wire closely spaced from said surface and a power supply applying of the order of thousands of volts to said
- 15 corona wire;
- 20 E. said imaging head for discharging portions of said electrostatic charge to effect on said surface a latent electrostatic image of certain discharged incremental image areas and other charged incremental areas, said imaging head including a linear array of heat elements capable of dissipating timed quantities of electrical energy therein, and further including
- 25 a covering over said heat elements linear array, said covering having an outer face slidably engaged with said surface as the member is moved therepast and facilitating transfer of said dissipated energy to said
- 30 barrier layer and coating under said certain incremental image areas to increase the heat energy thereof sufficiently to discharge said electrostatic charge thereover;
- 35 and

5 F. said toning means for toning said latent
electrostatic image by applying toner
particles to said surface to render visible
one of said certain discharged image areas
and said other charged image areas and to
10 leave clear the other of said certain
discharged image areas and said other
charged image areas.

27. A method of discharging in darkness portions of an
15 electrostatic charge carried on the top surface of the
photoconductive layer of an electrophotographic member,
the photoconductive layer being capable of accepting a
charge and retaining the charge to effect on said surface
certain discharged and other charged incremental image
20 areas forming a latent electrostatic image, c.i.t. said
discharging being effected by applying heat energy to
the charge carrying surface at localized areas at levels
below the energy level required to obtain the photocon-
ductive effect in said member to at least a portion of
25 the upper thickness of said member under said certain
incremental image areas.

30

35

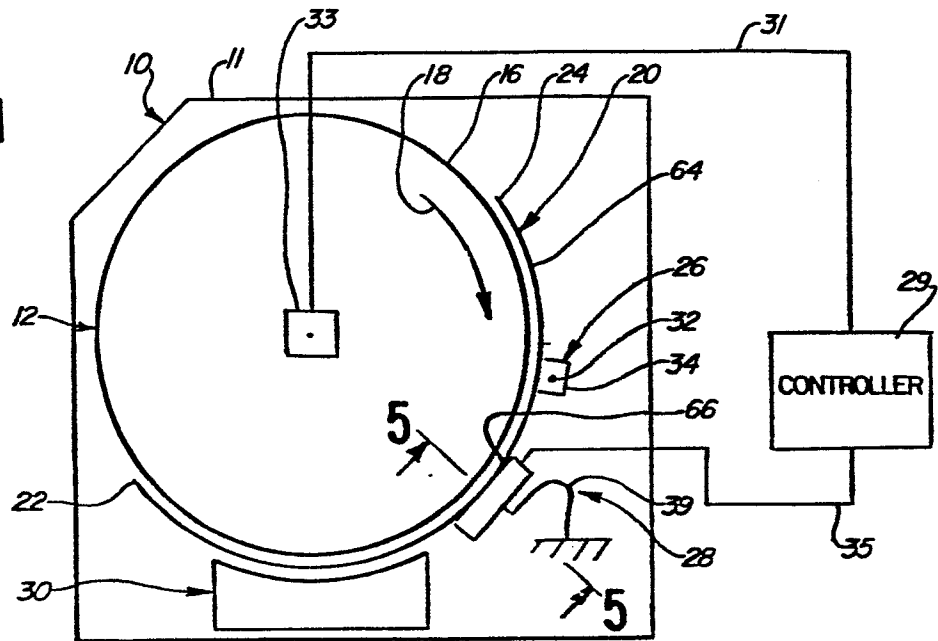


FIG. 2

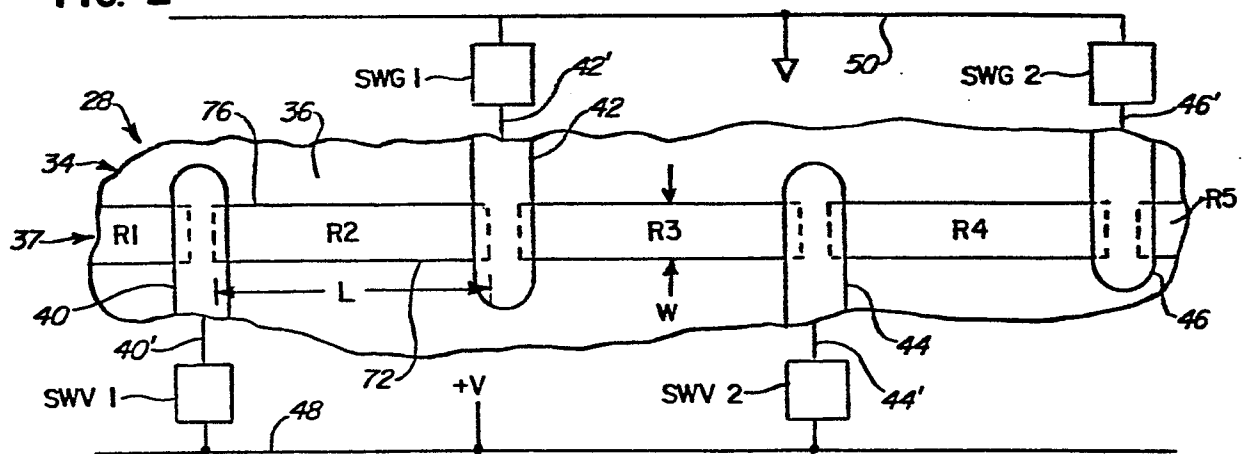


FIG. 3

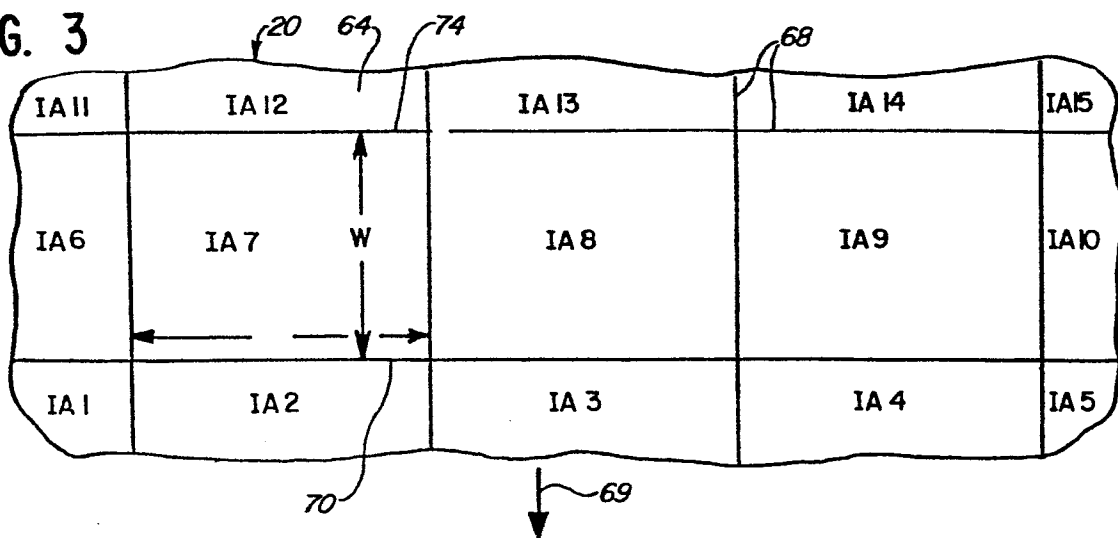


FIG. 4A

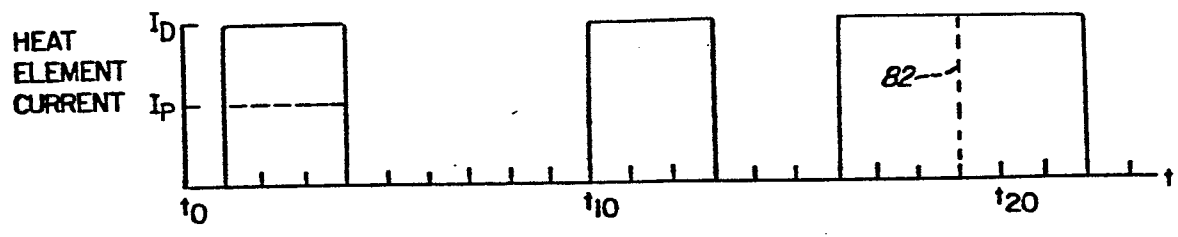


FIG. 4B

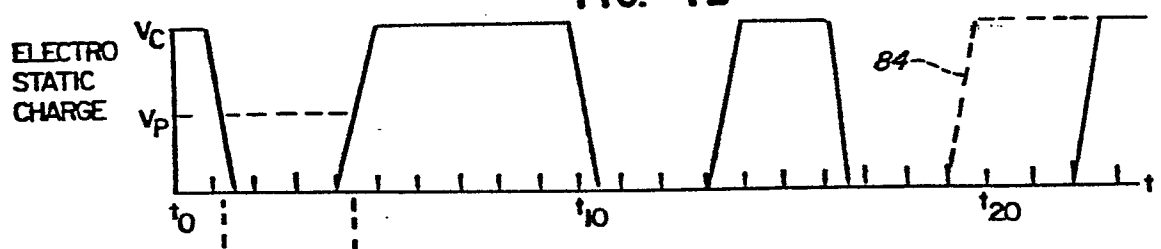


FIG. 4C

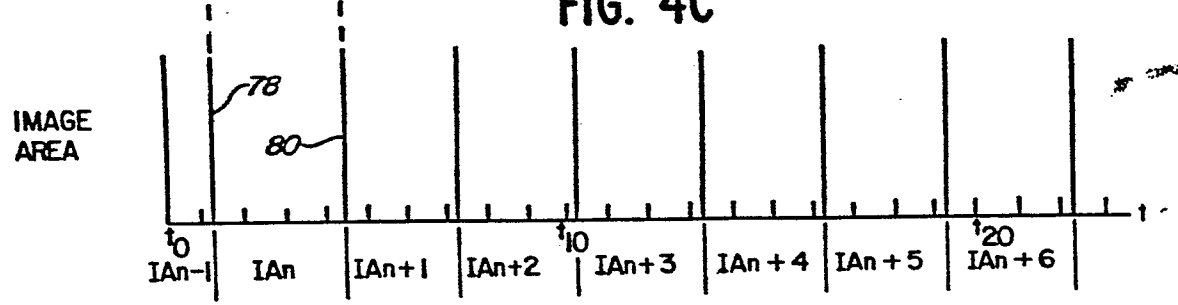
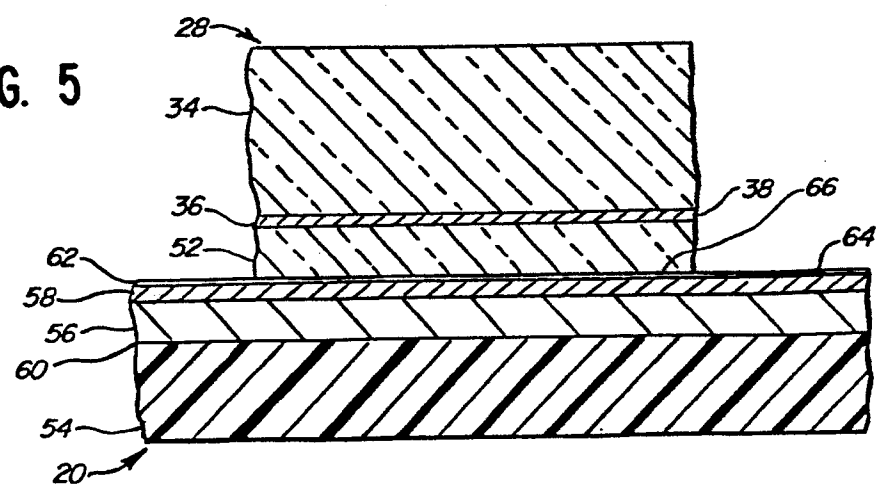


FIG. 5





European Patent
Office

EUROPEAN SEARCH REPORT

0190404

Application number

DOCUMENTS CONSIDERED TO BE RELEVANT			EP 85114055.8
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
	<u>GB - A - 1 028 997 (KODAK)</u>		G 03 G 15/12
Y	* Fig. 6; page 2, lines 82-84; pages 3,4; claim 1 *	1,19, 25,27	G 03 G 13/12
A	* Fig. 1-6; pages 2-4 *	6-8, 10,12-18,26	G 03 G 5/028
	--		
	<u>DE - A - 1 522 741 (ELEKTRONISCHE RECHENMASCHINEN)</u>		
Y	* Fig. 1; claims 1,4,5; page 5, lines 1-4,4-15 *	1,19, 25,27	
A	* Fig. 1; page 1, claims *	2-8, 10,12, 13,26,	
	--		
	<u>US - A - 4 025 339 (KUEHNLE)</u>		
D,Y	* Abstract; fig. 1-4,8,9 *	1,19, 25,27, 14	TECHNICAL FIELDS SEARCHED (Int. Cl.4)
A	--		
	<u>GB - A - 2 019 782 (ENERGY CONVERSION)</u>		G 03 G 15/00
A	* Fig. 1-7; abstract; page 1, lines 93-97; claims *	1-12, 14-23, 26	G 03 G 13/00
	--		
	<u>FR - A - 1 495 284 (TEXAS INSTRUMENTS)</u>		
A	* Fig. 1-6,9; claims *	1-5,12, 15-23, 26	
	--		
	<u>US - A - 3 128 198 (DULMAGE)</u>		
A	* Fig. 1A-2D; claims; column 2, line 64 - column 3, line 57 *	1-5, 19,25-27	
The present search report has been drawn up for all claims			
Place of search VIENNA		Date of completion of the search 26-03-1986	Examiner KRAL
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons A : member of the same patent family, corresponding document			