

[54] **MAGNETO-ELECTRIC APPARATUS
FOR REPRODUCING AN IMAGE ON A
RECORDING ELEMENT**

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118/637, 346/74 ES, 355/16, 355/5

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[58] Field of Search 355/3, 16, 17, 5; 346/74 ES;
118/637; 117/17.5; 96/1.3

[56] **References Cited**

UNITED STATES PATENTS

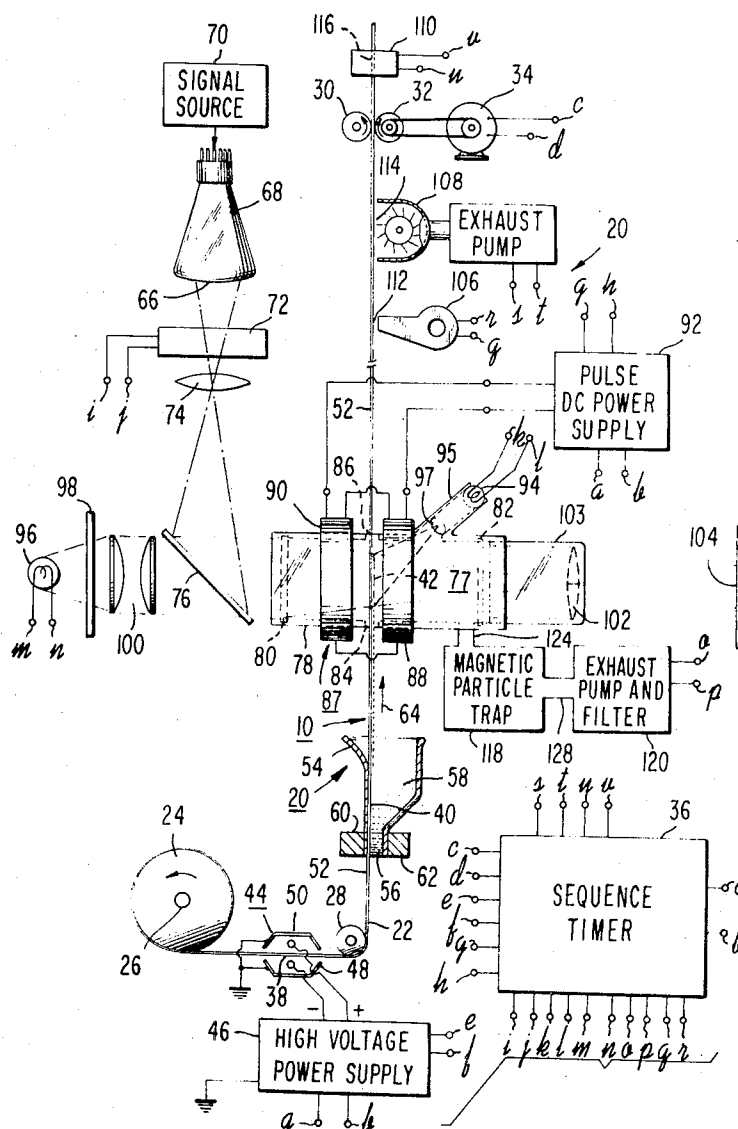
2,924,519	2/1960	Bertelsen	346/74 ES
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Attorney—Glenn H. Bruestle et al.

[57] **ABSTRACT**

An image is reproduced on the surface of a recording element, comprising a light-transmitting substrate and a photoconductive layer, by apparatus adapted to move the recording element past charging, toning, and image-exposing stations, in the order named. The recording element is uniformly charged, uniformly toned with magnetic toner particles, and exposed to a light image at the aforementioned stations, respectively. A magnetic field is disposed adjacent the image-exposing station to remove toner particles from the light-struck portions of the recording element during the exposure thereof, whereby to develop the image. The apparatus also includes means for projecting the developed image onto a screen, during, and after, the developing operation.

8 Claims, 4 Drawing Figures



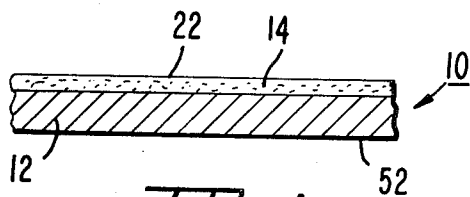


Fig. 1.

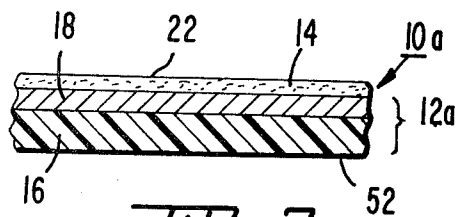


Fig. 2.

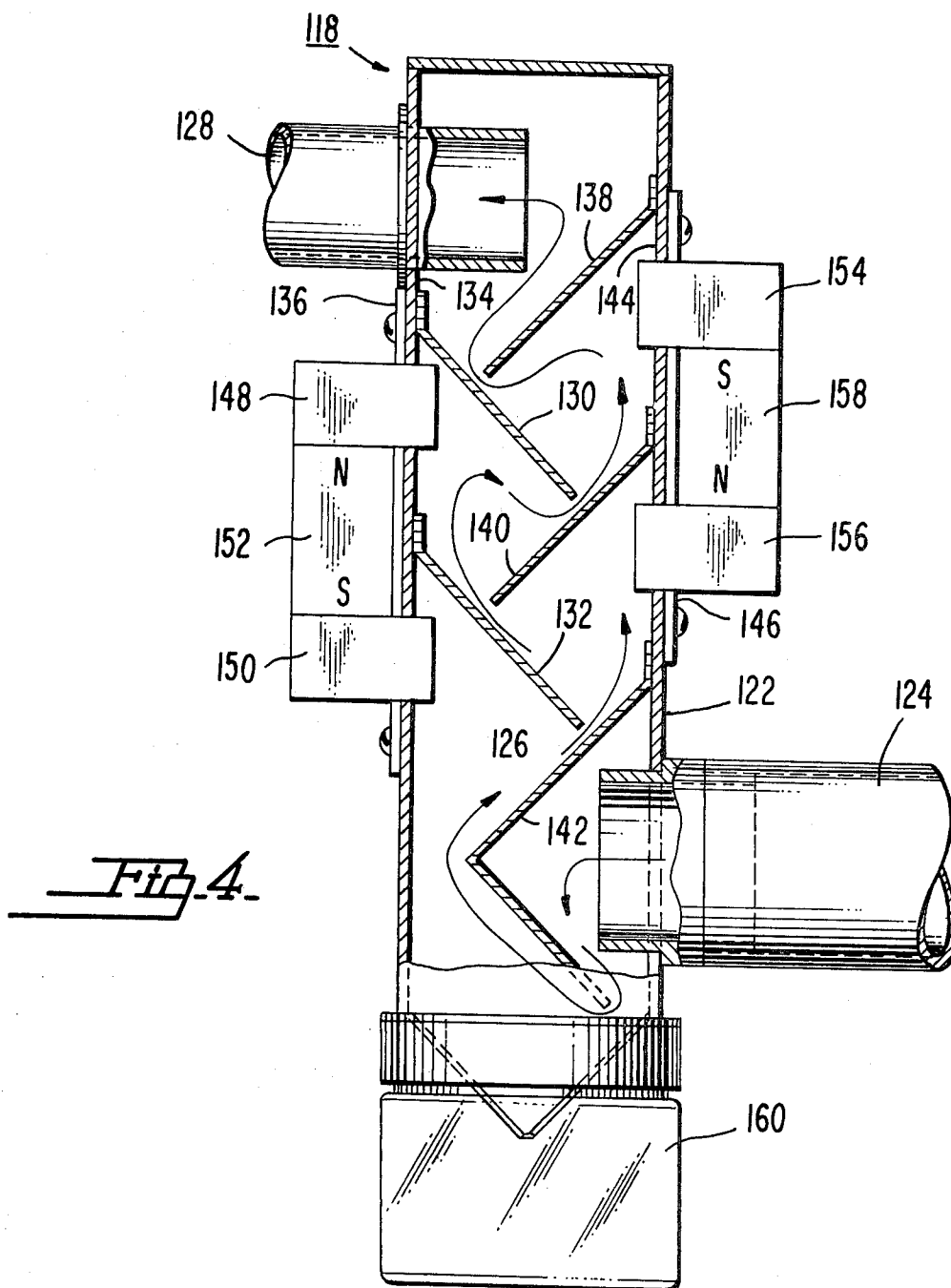
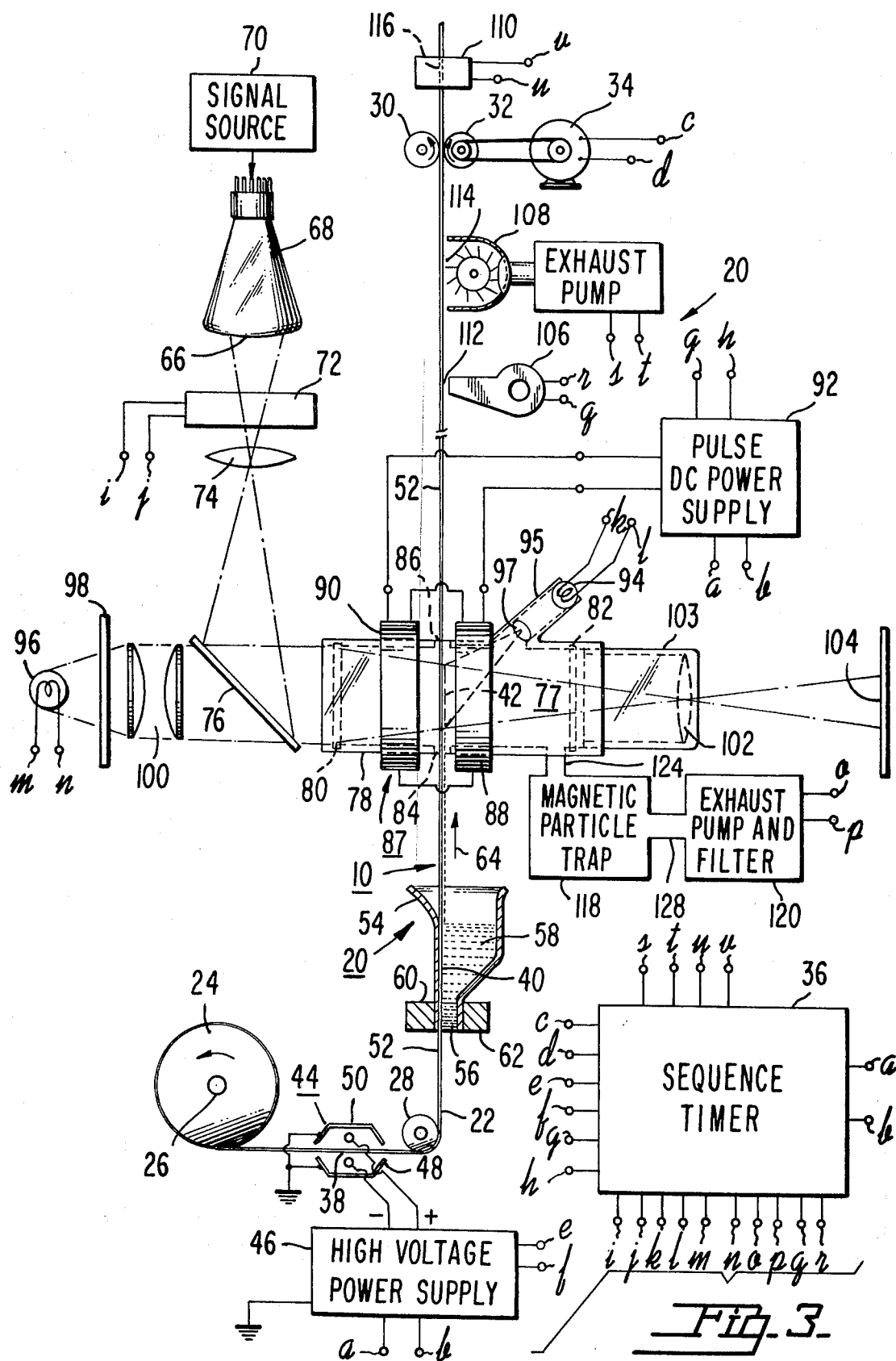


Fig. 4.

SHEET 2 OF 2



MAGNETO-ELECTRIC APPARATUS FOR REPRODUCING AN IMAGE ON A RECORDING ELEMENT

BACKGROUND OF THE INVENTION

This invention relates generally to magneto-electric apparatus, and more particularly, to magneto-electric apparatus for reproducing an image on the surface of a recording element in a continuous process.

It has been proposed to reproduce an image on the surface of a recording element with magnetic toner particles in a magneto-electric process wherein each of the operations is carried out manually. While such a process provides a satisfactory reproduction of an image, it is relatively laborious and time consuming in comparison to the reproduction of an image by the novel apparatus described herein.

SUMMARY OF THE INVENTION

The novel magneto-electric apparatus, in one embodiment of the invention, for reproducing an image on the surface of a recording element comprising a light-transmitting substrate and a photoconductive layer thereon, comprises means to move the recording element past charging, toning, and image-exposing stations, in the order named. The recording element is uniformly electrostatically charged and toned at the charging and toning stations, respectively, and then exposed to a light image of the image to be reproduced at the image-exposing station. A magnetic field, disposed adjacent to the image-exposing station, removes toner particles from portions of the surface of the recording element that are light-struck during the exposure, whereby to reproduce the image on the surface of the recording element.

In another embodiment of the novel apparatus, means are provided to observe the image being reproduced by projecting the developed image onto a surface from which it may be copied further.

In still another embodiment of the novel apparatus, a flood light is disposed adjacent the toned surface of the recording element at the image-exposing station for aiding in the developing process.

In a further embodiment of the novel apparatus, means are provided to fix the magnetic toner particles of the reproduced image to the surface of the recording element, and means are provided to cut the recording element from a continuous web thereof.

In still a further embodiment of the novel apparatus, means are provided to remove the magnetic toner particles of the reproduced image from the surface of the recording element, so that the recording element may be reused.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a fragmentary cross section of one example of a recording element that can be used with the novel apparatus;

FIG. 2 is a fragmentary cross section of another example of a recording element that can be used with the novel apparatus;

FIG. 3 is a schematic drawing, partly in cross-section and partly in block diagram form, of the novel magneto-electric apparatus for reproducing an image on the surface of a recording element of the type described in FIGS. 1 and 2; and

FIG. 4 is a cross-sectional view of the magnetic toner particle trap shown in block form in FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1 of the drawings, there is shown an electrophotographic recording element 10 of the type that can be used with the novel magneto-electric apparatus. The recording element comprises an electrically conductive, light-transmitting, substrate 12, such as paper having a moisture content of about 6 percent, for example; and an insulating (in darkness) photoconductive layer 14, such as, for example, zinc oxide, cadmium selenide, cadmium sulfide, each in a suitable resin binder, or polymerized vinylcarbazole compounds of the type described in U.S. Pat. No. 3,484,237 for "Organic Photoconductive Compositions and Their Use in Electrophotographic Process."

The substrate of the electrophotographic recording element may also comprise a transparent (or light-transmitting) plastic material coated with a thin, transparent, electrically conductive layer. Referring to FIG. 2, there is shown an electrophotographic recording element 10a whose substrate 12a comprises a substantially transparent plastic material, such as "Mylar," "Cronar" (E. I. DuPont De Nemours Co., Wilmington, Del.), or the like, coated with a thin, transparent, electrically conductive layer 18 of tin oxide, copper oxide, indium oxide, aluminum, or the like. The conductive layer 18 is coated with an insulating photoconductive layer 14, similar to the layer 14 in the electrophotographic recording element 10 in FIG. 1.

Referring now to FIG. 3 of the drawings, there is shown novel magneto-electric apparatus 20 for reproducing an image on a surface 22 of the photoconductive layer 14 of an electrophotographic recording element 10 (or 10a). The recording element 10, for example, is supplied to the apparatus 20 in a supply roll 24 disposed on a suitable mandrel 26. Means are provided to move a web of the recording element 10, from the supply roll 24, along a path determined by an idler roller 28 and a pressure roller 30. To this end, a driven roller 32, coupled to a motor 34 for rotation thereby, cooperates with the pressure roller 30 to unwind the recording element 10 from the supply roll 24 and to move it along a predetermined path.

A sequence timer 36, having a pair of input terminals a and b, for connection to a source of suitable electrical energy, has a plurality of pairs of output terminals for energizing the different components of the novel apparatus 20 at appropriate times, as will hereinafter be explained. For example, the motor 34 has a pair of input terminals c and d for connection to the output terminals c and d of the sequence timer 36 to move the recording element 10 along a path past a charging station 38, a toning station 40, and an image-exposing station 42, in the order named. The sequence timer 36 may be of the type wherein a motor rotates a shaft with a plurality of cams thereon. Each cam is adapted to energize a particular circuit at a particular time in the sequence of operations performed by the apparatus, in a manner well known in the art.

Means are provided to charge the surface 22 of the recording element 10 at the charging station 38. To this end, a double corona charging device 44 of the type well known in the electrophotographic printing art, is

disposed adjacent opposite major surfaces of the recording element 10 and connected to a high-voltage (about 10,000 Volts) power supply 46. A corona discharge device 48 of the double corona discharge device 44 is connected to the power supply 46 to apply a negative charge to the surface 22 of the recording element 10; and a corona discharge device 50 of the double corona discharge device 44 is connected to apply a positive charge to the opposite surfaces 52 of the recording element 10. The polarities of the charges applied to the surfaces 22 and 52 of the recording element 10 will depend upon the type of photoconductive layer employed, since it has been found that some photoconductive layers accept a charge of one polarity more easily than a charge of the opposite polarity. The power supply 46 has one pair of input terminals *a* and *b* for applying a source of suitable electrical energy thereto, and another pair of input terminals *e* and *f* for connection to terminals *e* and *f* of the sequence timer 36 for energizing the power supply 46 at appropriate times.

The recording element 10 is uniformly electrostatically charged at the charging station 38, in darkness, and moved (in darkness), via motor 34, to the toning station 40. Means are provided at the toning station 40 to uniformly tone the surface 22 with magnetic toner particles. To this end, there is provided a generally Vee-shaped reservoir 54 formed with a relatively narrow entrance slit 56. The reservoir 54 is filled with a quantity of magnetic toner particles 58, such as particles of iron, nickel, and cobalt, for example, having an average diameter of about 5 microns. This average diameter, however, is not critical. If the toner particles 58 are eventually to be erased from the recording element 10, the magnetic toner particles 58 may, or may not, be colored and/or coated. If, however, the toner particles 58 are to be fixed to the recording element 10, as by heat, they may be coated with a thermoplastic material, as described, for example, in U.S. Pats. Nos. 3,526,191, 3,106,479, or 3,093,039.

The narrow entrance slit 56 of the reservoir 54 has two bar magnets 60 and 62 fixed to the reservoir 54 on opposite sides of the slit 56 with their poles disposed to create a strong magnetic field within the slit 56, whereby to prevent any toner particles 58 from falling through the slit 56.

The uniformly electrostatically charged surface 22 of the recording element 10 is uniformly coated with magnetic toner particles 58 as it is moved through the reservoir 54 in the direction indicated by the arrow 64. The toner particles 58 are held on the charged surface 22 by electrostatic attraction. The electrostatic forces can be weakened by exposing the photoconductive layer 14 to light, as when the photoconductive layer is exposed by a light image to be reproduced.

The uniformly toned recording element 10 is next moved (in darkness) to the image-exposing station 42, and the motor 34 is stopped by the sequence timer 36. The recording element is now in a position to be exposed by the image to be reproduced thereon.

Let it be assumed, for example, that an image on the face 66 of a cathode ray tube 68 is to be reproduced on the surface 22 of the recording element 10. The image 66 may be derived from a suitable signal source 70, such as, for example, a television receiver. The image

on the face 66 of the cathode ray tube 68 is directed onto the light-transmitting substrate 12 of the recording element 10 through a shutter 72, a lens system, designated herein simply by a lens 24, and a mirror 76. The mirror 76 is partially light-transmitting and partially light-reflecting. The mirror 76 reflects the image through the light-transmitting substrate 12 and onto the photoconductive layer 14 of the recording element 10.

The image-exposing station 42 is within a tubular member 78. One end of the tubular member 78 is closed with a transparent quartz window 80. Another transparent quartz window 82 is disposed adjacent the other end of the tubular member 78 to provide a chamber for the purpose hereinafter appearing. The tubular member 78 is formed with a pair of opposite slits 84 and 86 to permit the recording element to pass therethrough.

Means are provided to create a magnetic field adjacent the image-exposing station 42 in a direction to pull the magnetic toner particles 58 away from the surface 22 of the recording element 10 when the recording element 10 is exposed with the light image to be reproduced thereon. Thus, two coils 88 and 90, each disposed adjacent a different one of the major surfaces 22 and 52, respectively, of the recording element 10, are connected in circuit with a pulsed dc power supply 92 for energizing them so that they function as an electromagnet 87. The power supply 92 preferably supplies unfiltered, full-wave rectified, half sine wave, direct current pulses that can be varied in magnitude so as to control the magnetic field to a desired strength. The desired strength is usually just insufficient to pull the magnetic toner particles 58 from the surface 22 of the recording element 10 in the absence of an image exposure of the recording element 10. An image exposure of the recording element 10 would increase the photoconductivity of the photoconductive layer 14, and thereby reduce the electrostatic attraction between the toner particles 58 and the light-struck portions of the recording element 10. Hence, the affected toner particles 58 (adjacent the light-struck portions of the photoconductive layer) would be pulled away from the surface 22 by the magnetic field.

The power supply 92 is provided with one pair of input terminals *a* and *b* for connection to a suitable source of electrical energy, and another pair of output terminals *g* and *h* for connection to the terminals *g* and *h* of the sequence timer 36 to energize the electromagnet 87 at appropriate times, as will hereinafter be explained. The shutter 72 also has a pair of input terminals *i* and *j* for connection to the terminals *i* and *j* of the sequence timer 36 for opening the shutter at a predetermined time to let the image on the face 66 of the cathode ray tube 68 to be directed to the recording element 10.

A flood light 94 is disposed adjacent the surface 22 at the image-exposing station 42 for flooding the toned surface with light during the developing of the image to be reproduced, as will hereinafter be explained. The flood light 94 has a pair of terminals *k* and *l* for connection to the terminals *k* and *l* of the sequence timer 36 to energize the flood light 94 at the appropriate time. The flood light 94 is disposed within a housing 95 that communicates with the tubular member 78. A lens 97 directs light from the flood light 94 to the surface 22.

Means are provided to view and/or monitor the image reproduced on the surface 22 of the recording element 10 during the exposure of the recording element 10 with the light image, that is, during the development of the toned image. To this end, a lamp 96 is disposed to send a beam of light through: a filter 98; a condenser 100; the light-transmitting mirror 76; the quartz windows 80 and 82; the recording element 10; and objective lens 102, having a housing 103 that communicates with the tubular member 78; and onto a planar surface 104. The lamp 96 has a pair of terminals *m* and *n* for connection to a pair of terminals *m* and *n* on the sequence timer 36 for activating the lamp 96 at the appropriate time. The image projected onto the planar surface 104 may be reproduced again by any suitable image reproduction device disposed thereat.

Other components, such as a heater 106, a toner particle eraser 108, comprising a brush 109 and an exhaust pump 11, and a cutter 110, may be placed along the path of travel of the recording element 10 at fixing, erasing, and cutting stations, 112, 114, and 116, respectively. The heater 106 has a pair of input terminals *q* and *r*, the pump 111 has a pair of input terminals *s* and *t*, and the cutter 110 has a pair of input terminals *u* and *v* for connection to corresponding terminals *q* and *r*, *s* and *t*, and *u* and *v* of the sequence timer 36 for operating these components, respectively, at desired times. All of these components may not be used depending upon the pre-setting of the sequence timer 36, as will hereinafter be explained.

During the exposure of the recording element 10 with the image to be reproduced thereon at the exposure station 42, toner particles 58 are removed from the uniformly toned surface 22, at the light-struck areas thereof, by the magnetic field; and it is necessary to remove these toner particles 58 from the tubular member 78 where they would otherwise collect. Means are provided to remove these toner particles 58 during the image-exposure period. To this end, a magnetic particle trap 118 is connected to the tubular member 78 adjacent the surface 22 of the recording element 10. The trap 118 is connected to an exhaust pump 120 and filter for drawing the toner particles 58 through the magnetic trap 118. The exhaust pump 120 has a pair of terminals *o* and *p* for connection to the terminals *o* and *p* of the sequence timer 36 for operating the exhaust pump at the desired time.

Referring now to FIG. 4 of the drawings, the magnetic toner particle trap 118 is shown in detail. The trap 118 comprises an enclosed tubular housing 122 of non-magnetic material, having substantially rectangular cross section. An inlet tube 124, adjacent one end of the trap 118, connects the interior 126 of the trap 118 with the interior 77 of the tubular member 78. An outlet tube 128, adjacent the other end of the trap 118, connects the interior 126 of the trap 118 of the exhaust pump 120 and filter. A set of a plurality of spaced-apart baffle plates, such as baffle plates 130 and 132, extend outwardly and downwardly from the interior surface 134 of a vertical wall 136 of the trap 118. Another set of spaced-apart baffle plates, such as baffle plates 138, 140, and 142, extend outwardly and downwardly from an interior surface 144 of a wall 146, opposite to the wall 136, of the trap 118. The two sets of baffles are disposed so as to provide a tortuous path for the flow of air from the inlet tube 124 to the outlet tube 128.

Means are provided on the exterior surfaces of the walls 136 and 146 to trap 118 and to hold magnetic toner particles 58 that are removed, in the air flow, from the interior of the tubular member 78. To this end, a pair of spaced-apart soft iron pole pieces 148 and 150 are fixed to the exterior surface of the wall 136, and a removable permanent magnet 152 is slidably disposed between the pole pieces 148 and 150. In a similar manner, a pair of spaced-apart pole pieces 154 and 156 are fixed to the exterior surface of the wall 146, and a permanent magnet 158 is slidably disposed between the pole pieces 154 and 156.

In operation, any toner particles 58 that are sucked into the trap 118 are forced to travel along the tortuous path between the baffle plates 142, 132, 140, 130, and 138. Some of the toner particles are trapped by the baffle plates themselves, and the remainder of the toner particles 58 adhere to the interior surfaces of the walls 136 and 146, trapped by a magnetic field produced by the pole pieces 148, 150, 154, and 156, and the permanent magnets 152 and 158. The magnetic toner particles 58 may be recovered in a receptacle, such as a jar 160, disposed at, and communicating with, the lowest portion of the trap 118, by shutting off the exhaust pump 120 and then slidably removing the permanent magnets 152 and 158. Since the walls of the trap 118 are non-magnetic, the magnetic toner particles 58 fall into the receptacle 160 from which they may be recovered and reused.

The operation of the magneto-electric apparatus 20 for reproducing an image, from the face 66 of the cathode ray tube 68, onto the surface 22 of the recording element 10 will now be described. The web of the recording element 10 is threaded through the charging station 38, the toning station 40, and the image-exposing station 42 and engaged between the pressure roller 30 and the driven roller 32, as shown in FIG. 3. The recording element 10 is electrostatically charged, applying a negative charge to the surface 22 of a positive charge to the opposite surface 52 of the recording element 10. At the time the recording element 10 is being charged, it is also being moved from the charging station 38 to the toning station 40.

As the recording element 10 is moved through the reservoir 54, at the toning station 40, magnetic toner particles 58 uniformly tone the surface 22. The uniformly toned surface 22 is next moved into the image-exposing station 42 and the motor 34 is stopped. The shutter 72 is opened and the image on the face 66 of the cathode ray tube 68 is directed and focused onto the recording element 10 by the lens system 74 and the mirror 76. The coils 88 and 90 are energized to create a magnetic field, and the exhaust pump 120 is energized. The flood light 94 is also energized to flood the toned surface 22 with light. Under these conditions, the projected light image (from face 66) increases the photoconductivity of the photoconductive layer 14 at the light-struck portions thereof. The increased photoconductivity reduces the electrostatic attraction between the toner particles 58 and the recording element 10 at the light-struck portions so that the magnetic field can pull the affected toner particles 58 away from the surface 22, and thereby, cause the image to be reproduced on the surface 22.

Light from the flood light 94 further increases the photoconductivity of the photoconductive layer 14 at

the light-struck portions exposed by the removal of toner particles 58 and this helps speed up the formation of the image. The removed toner particles 58 are caught in the trap 118 in the manner described, supra.

The development on the surface 22 of the recording element 10 can be observed on the planar surface 104 by energizing the lamp 96 so that the image formation on the surface 22, at the image-exposing station 42, can be projected onto the surface 104. In this manner, the development of the image on the recording element 10 can be monitored and stopped, as by deenergizing the pulse power supply 92, when the desired image is reproduced.

When the lamp 96 is used to view the formation of the reproduced image on the surface 22 of the recording element 10, light from the lamp 96 does not affect the photoconductivity of the photoconductive layer 14 if the filter 98 only allows those wavelengths of light from the lamp 96 to pass through that do not affect the photoconductivity of the photoconductive layer 14. For example, if the filter 98 is a filter which prevents ultraviolet light from passing through, and if the photoconductive layer is responsive only to ultraviolet light, light from the lamp 96 will not affect the development of the image on the surface 22. After the image is reproduced on the surface 22, however, the lamp 96 can project light of any wavelength onto the surface 104, as long as the magnetic field produced by the coils 88 and 90 is turned off.

If it is not desired to save the image reproduced on the surface 22, the reproduced image can be erased at the erasing station 114 by the toner particle eraser 108 so that the recording element 10 may be reused. It is also within the contemplation of the present apparatus to use a recording element 10 in the form of an endless belt on which an image may first be reproduced, viewed or projected, and then erased after it has served its purpose.

If, on the other hand, it is desired to preserve the image reproduced on the surface 22 of the recording element 10, toner particles 58 that are coated with a thermoplastic coating may be used, and the reproduced image of toner particles 58 can be heated by the heater 106 at the fixing station 112. Under these conditions, the thermoplastic coating on the toner particles 58 melt and stick to the surface 22, thereby producing a permanent image thereon. It is also within the contemplation of the present invention to fix uncoated toner particles 58 to the surface 22 by spraying the reproduced image of toner particles 58 with a spray of adhesive material, such as, for example, shellac. A desired length of the web of the recording element 10 can be cut off by the cutter 110 at the cutting station 116.

The novel magneto-electric apparatus 20 may be utilized in many different applications from those explained supra, some of which are as follows: Another means of erasing the reproduced toned image, after it has been viewed, is to increase the strength of the magnetic field and to flood the image with light at the image-exposing station 42, to completely overcome the electrostatic forces holding the toner particles 58 to the surface 22. Another means of exposing the recording element is to produce double exposures at the image-exposing station 42, by exposing the toned recording element successively with two (or more) images to be

reproduced. The time of exposure and the strength of the magnetic field applied for each successive exposure may have to be adjusted to account for the decrease in the electrostatic forces in the remaining toned areas of the recording element as they may become modified by spontaneous dark-decay effects. Another application of the flood light 94, for example, can be to project (by reflection) the fully developed image reproduced on the surface 22 onto the plane surface 104, after the magnetic field has been removed. These applications and functions can be programmed into the sequence timer 36 for automatic operations, in a manner well known in the art.

I claim:

1. Magneto-electric apparatus for reproducing an image on the surface of a recording element, comprising a light-transmitting substrate and a photoconductive layer thereon, said apparatus comprising:

means to move said recording element past a charging station, a toning station, and an image-exposing station, in the order named,

means to apply a uniform electrostatic charge to said surface at said charging station,

means to tone said surface uniformly with magnetic toner particles at said toning station,

means to expose said photoconductive layer through said substrate with the image to be reproduced at said image-exposing station, and

means adjacent said image-exposing station to apply a magnetic field to said toner particles in a direction, and of a strength, to remove toner particles from portions of said surface that are light-struck during the exposure by the image to be reproduced, whereby to develop the image to be reproduced on said surface.

2. Magneto-electric apparatus for reproducing an image on the surface of a recording element, as described in claim 1, wherein

a flood light is disposed adjacent said image-exposing station and adapted to direct light onto the toned surface of said recording element during the exposure thereof by said image to be reproduced, whereby to assist in the development of said image.

3. Magneto-electric apparatus for reproducing an image on the surface of a recording element, as described in claim 1, wherein

said means to apply a magnetic field to said toner particles comprises an electromagnet and means to energize said electromagnet with voltage pluses.

4. Magneto-electric apparatus for reproducing an image on the surface of a recording element, as described in claim 3, wherein

said electromagnet comprises two spaced-apart, substantially parallel, coils, and said image-exposing station is located between said two coils.

5. Magneto-electric apparatus for reproducing an image on the surface of a recording element, as described in claim 1, wherein

said means to move said recording element past a charging station, a toning station, and an image-exposing station comprises, in addition,

means to move said recording element past an erasing station for removing said toner particles from

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said surface, whereby said recording element may be reused.

6. Magneto-electric apparatus for reproducing an image on the surface of a recording element, as described in claim 1, wherein

means are cooperatively associated with said means to expose said photoconductive layer to project and to monitor the development of the image reproduced on said surface during 3/27/72 E C G , and after, the exposure thereof.

7. Magneto-electric apparatus for reproducing an image on the surface of a recording element, as described in claim 1 comprising, in addition, a fixing station, and

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said means to move said recording element comprises, in addition, means to move said recording element past said fixing station for fixing said toner particles to said surface.

8. Magneto-electric apparatus for reproducing an image on the surface of a recording element, as described in claim 1, wherein

said magnetic toner particles are coated with a thermoplastic material, and

means are provided to fix the coated magnetic toner particles to said surface after the image to be reproduced has been developed on said surface.

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