

[72] Inventors Yoshiki Hayashi
Osaka;
Yoshihiko Yamamoto, Nara; Kenichi Hirai,
Osaka; Isao Ota, Osaka, all of, Japan
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[73] Assignee Matsushita Electric Industrial Co., Ltd.
Kadoma, Osaka, Japan
[32] Priority Sept. 22, 1967
[33] Japan
[31] 42/61,355

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Primary Examiner—Samuel S. Matthews
Assistant Examiner—Monroe H. Hayes
Attorney—Wenderoth, Lind and Ponack

[54] ELECTROPHOTOGRAPHIC MOTION PICTURE APPARATUS 7 Claims, 24 Drawing Figs.

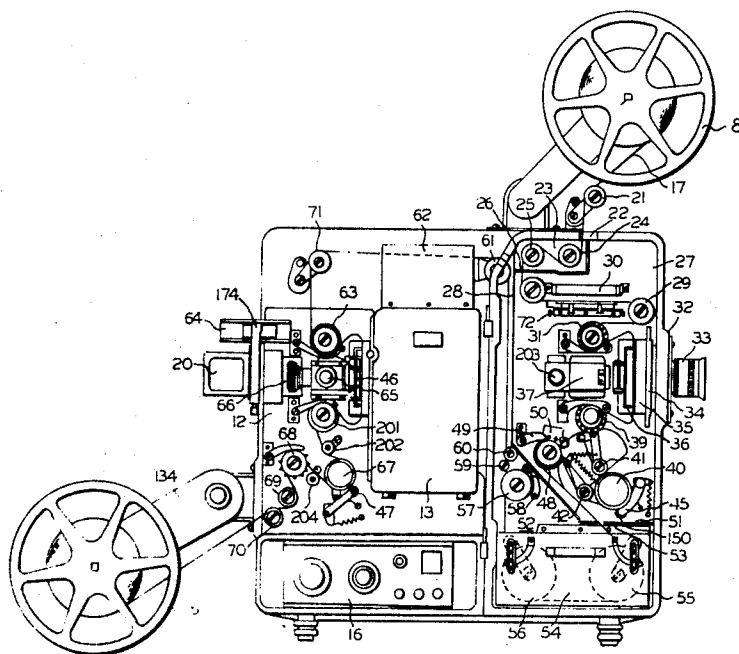
[52] U.S. Cl. 352/138,
95/1.7, 352/29, 355/5
[51] Int. Cl. G03b 19/18
[50] Field of Search. 352/29,
138, 244; 95/1.7; 355/5

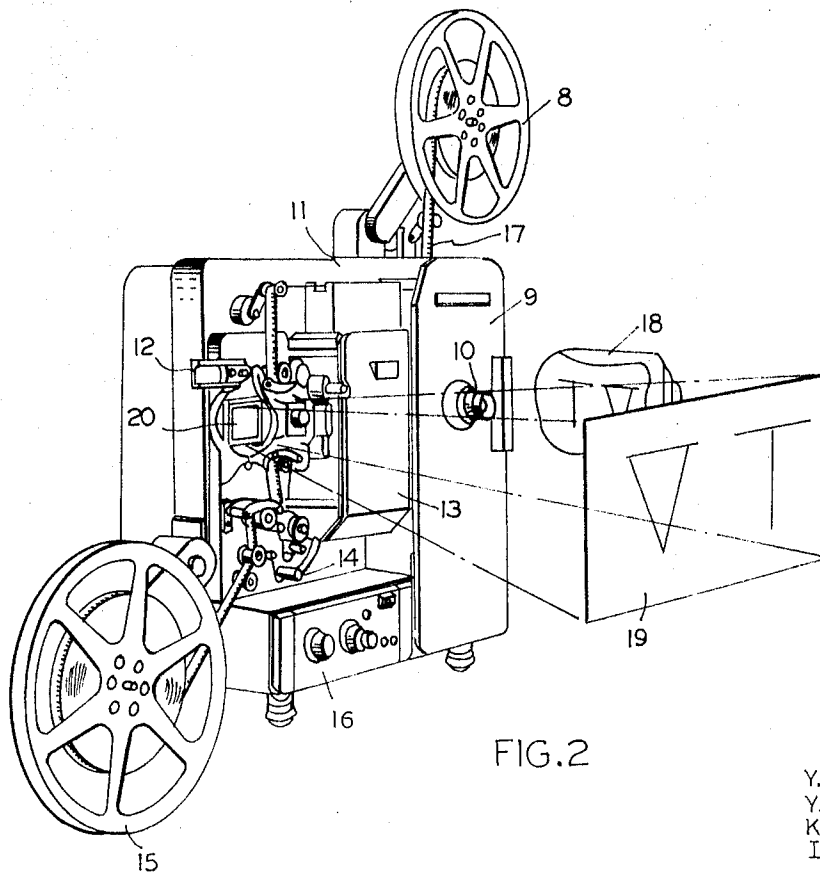
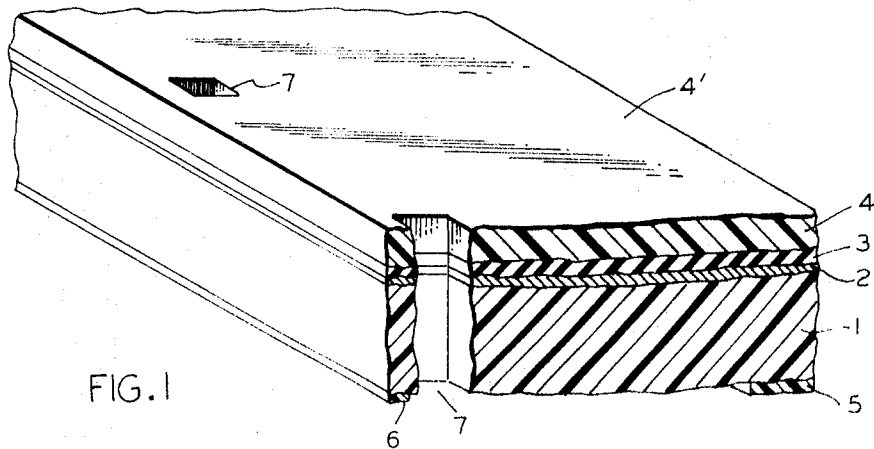
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ABSTRACT: An electrophotographic apparatus utilizing a substantially flexible and transparent film which comprises laminations consisting in the following order from the bottom up, a transparent polymer sheet, a transparent conductive layer, a transparent adhesive layer, and an organic photoconductive insulating layer, and which further comprises a magnetic sound track on the back face thereof.

The apparatus has a corona discharge mechanism for applying in the dark a uniform electrostatic charge to the photoconductive top surface of the film; exposure apparatus for intermittently exposing the photoconductive surface of the film to a visible light ray image while simultaneously recording the corresponding sounds on the sound track; developing apparatus for applying in the dark a dispersion type liquid developer to the photoconductive surface of the film so as to produce a visible image on the surface; projection apparatus for intermittently projecting the visible images which are produced and simultaneously reproducing the corresponding sounds which were recorded on the sound track; and a mechanism for rewinding the developed and sound-recorded film for preservation.





INVENTORS

Y. HAYASHI
Y. YAMAMOTO
K. HIRAI
I. OTA

BY

Wendroth, Lund & Tonack

ATTORNEYS

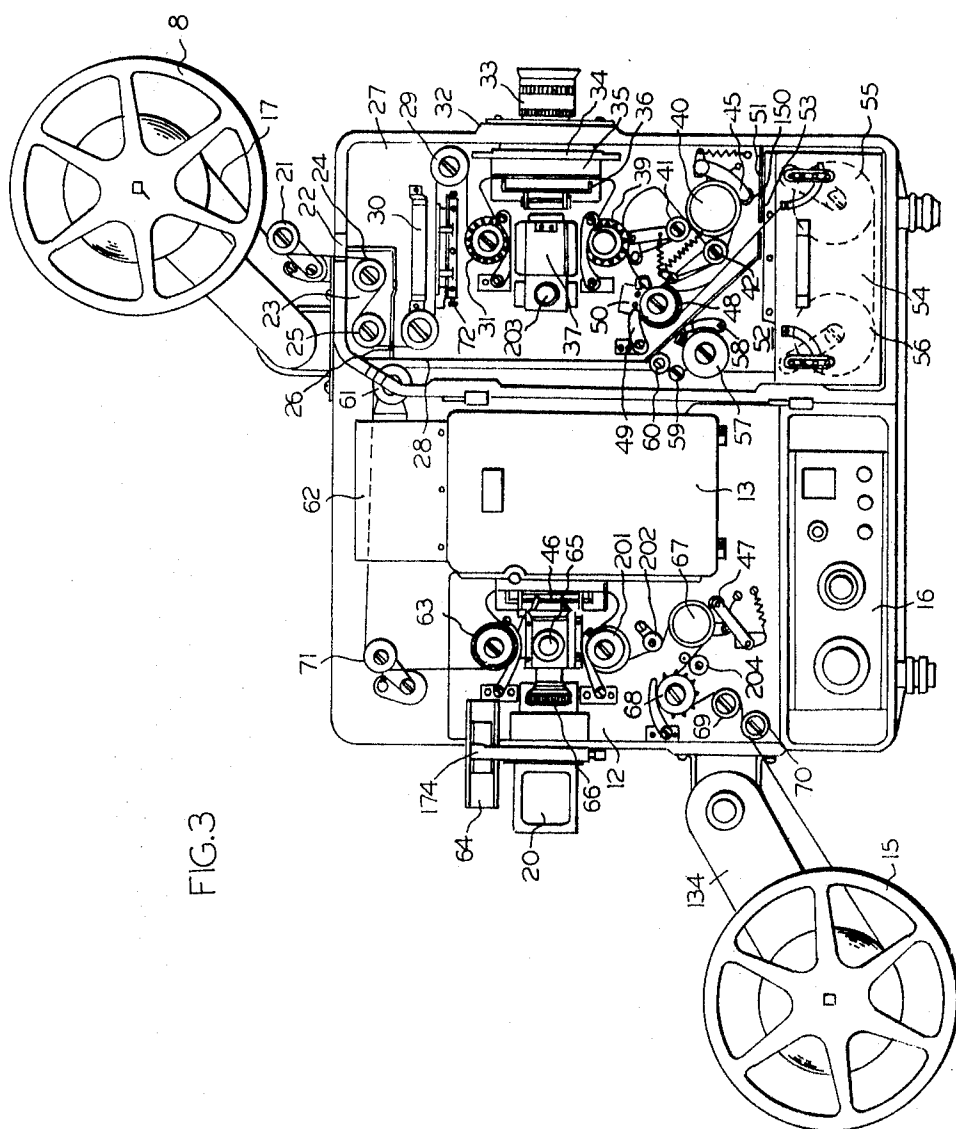


FIG. 3

INVENTORS
Y. HAYASHI
Y. YAMAMOTO
K. HIRAI
I. OTA

BY *Wendroth, Lind & Ponack*
ATTORNEYS

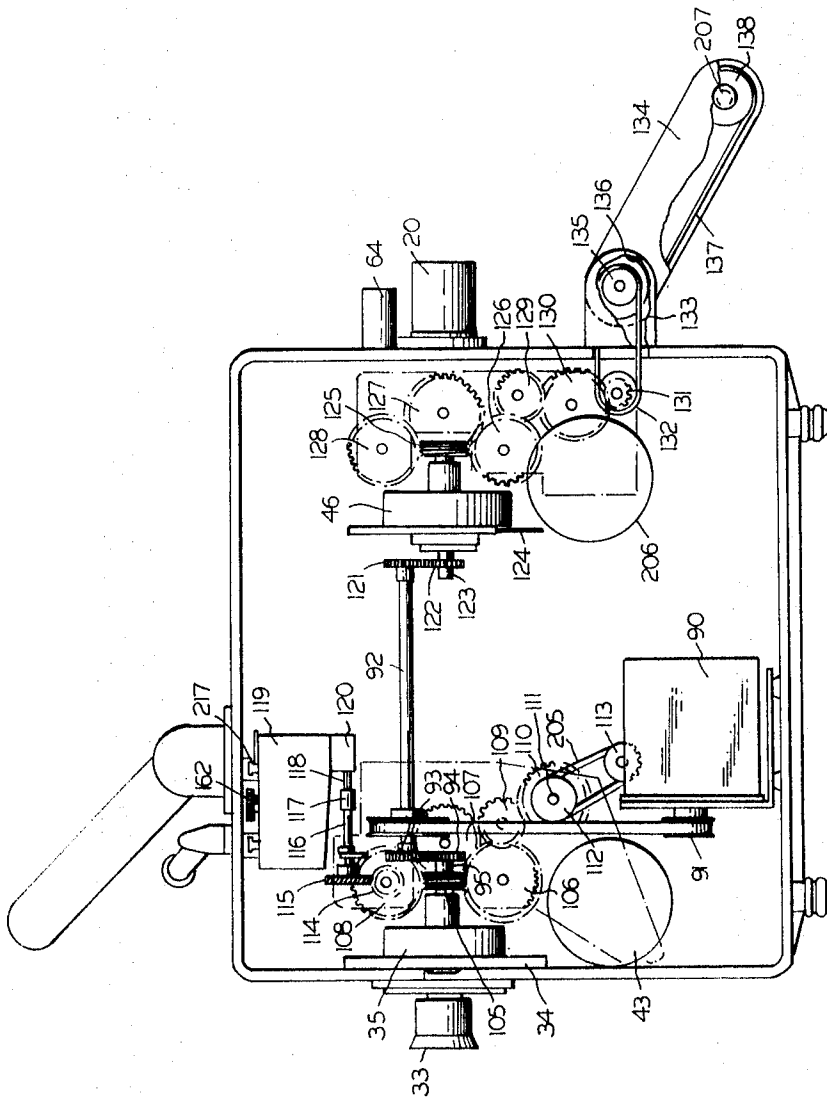


FIG. 4

INVENTORS

Y. HAYASHI
Y. YAMAMOTO
K. HIRAI
I. OTA

BY

Wendroth, Lund & Ponack

ATTORNEYS

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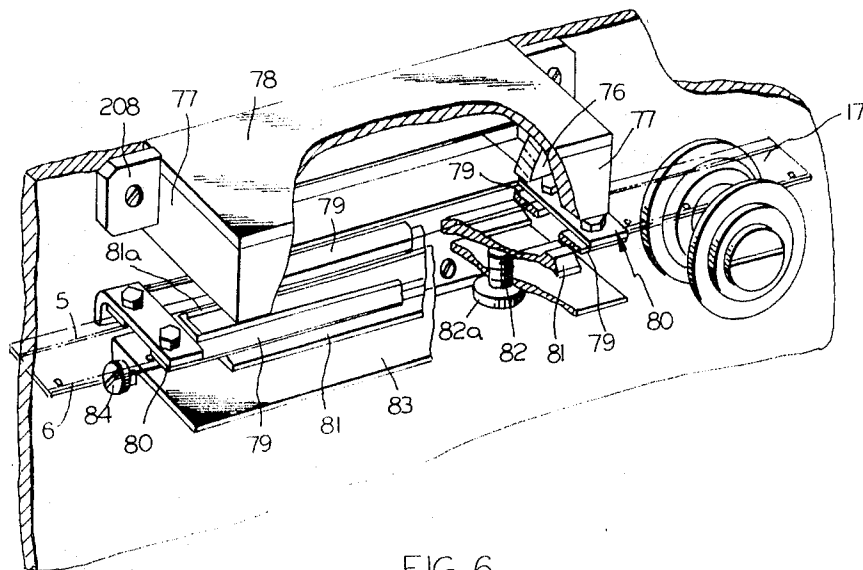


FIG. 6

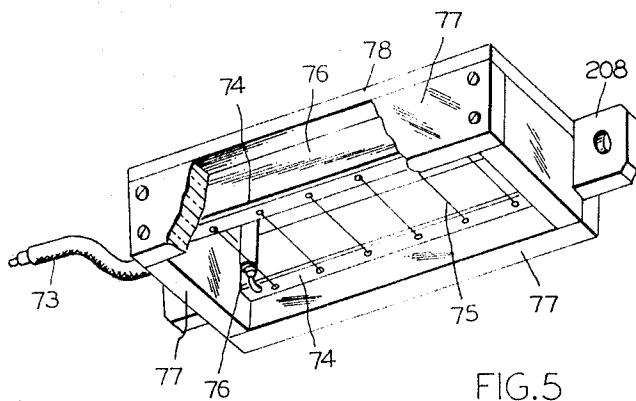


FIG. 5

INVENTORS

Y. HAYASHI
Y. YAMAMOTO
K. HIRAI
I. OTA

BY

Wendroth, Lind & Ponack

ATTORNEYS

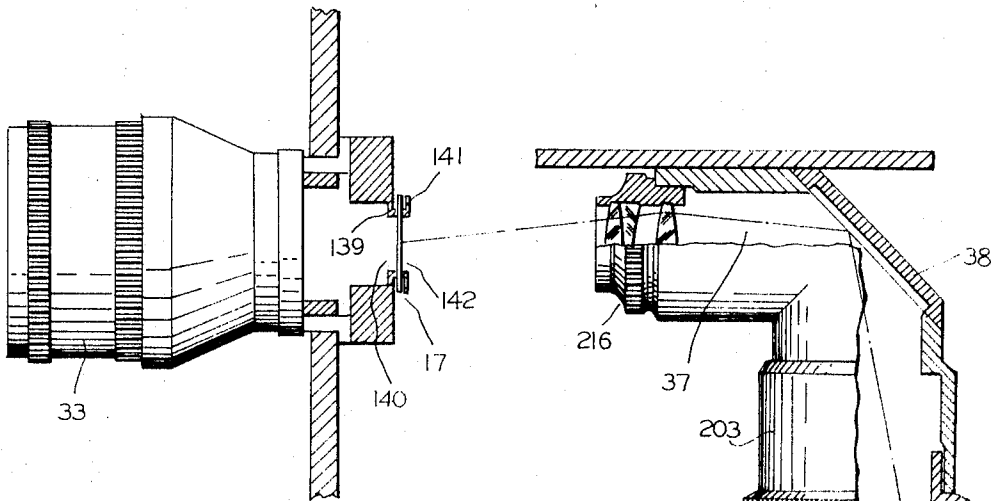


FIG. 8

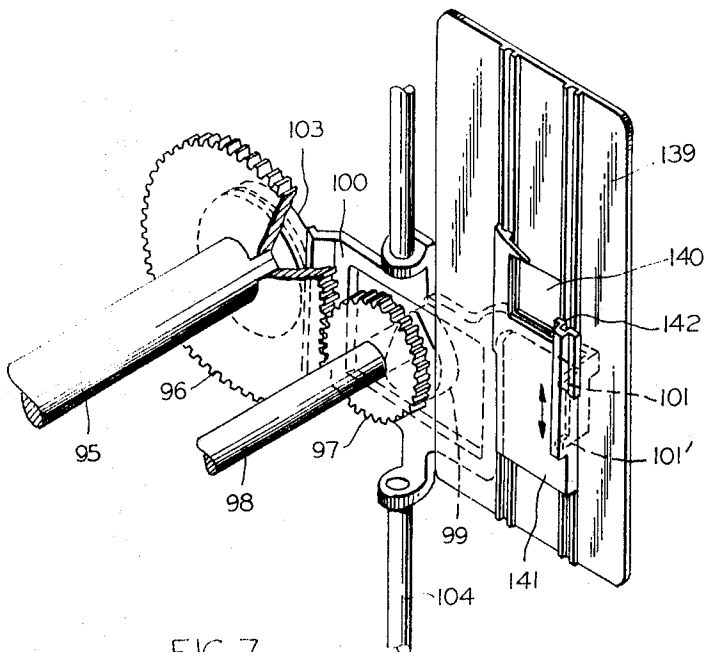


FIG. 7

INVENTORS
Y. HAYASHI
Y. YAMAMOTO
K. HIRAI
I. OTA

BY *Wendroth, Lund & Pnack*
ATTORNEYS

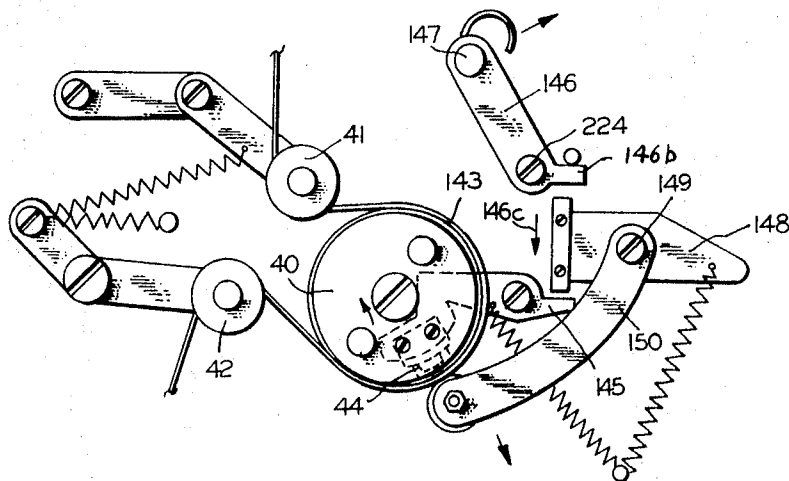


FIG. 9b

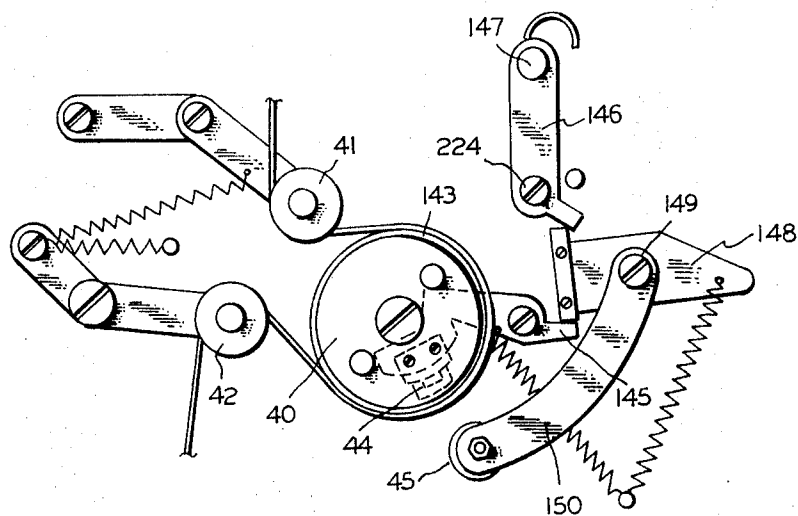


FIG. 9c

INVENTORS
Y. HAYASHI
Y. YAMAMOTO
K. HIRAI
I. OTA

BY *Wendroth, Lind & Tonack*
ATTORNEYS

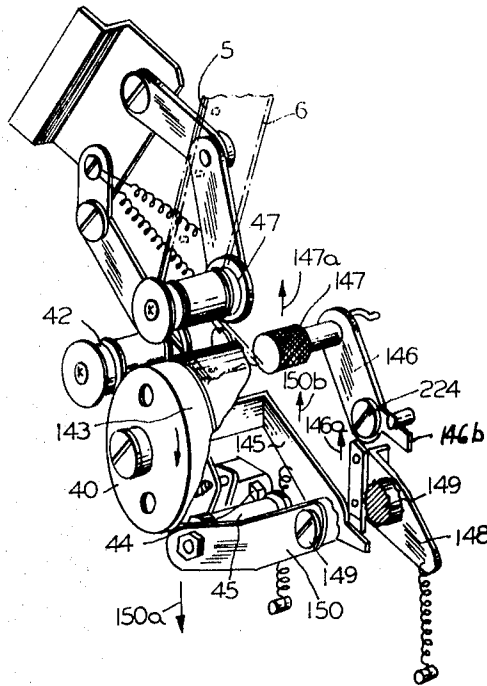


FIG. 9a

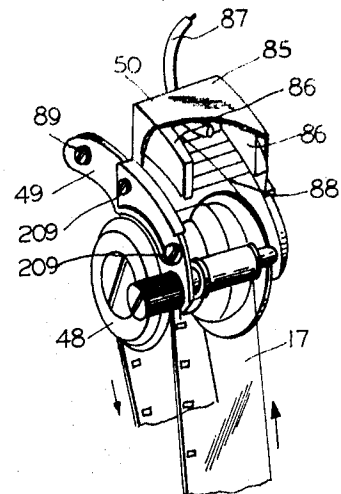


FIG. 10

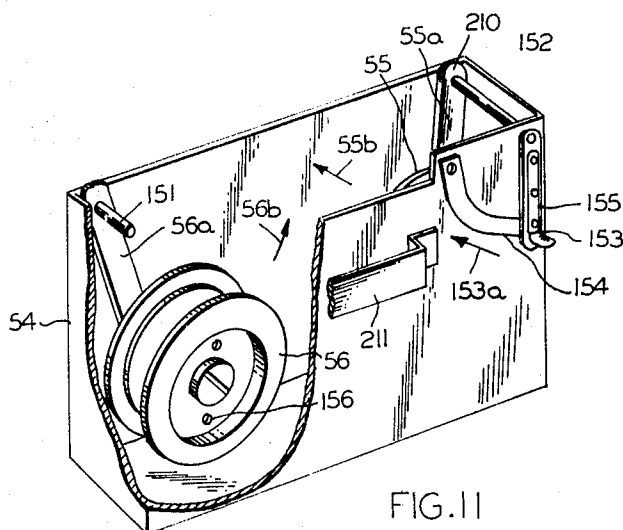


FIG. 11

INVENTORS
Y. HAYASHI
Y. YAMAMOTO
K. HIRAI
I. OTA

BY *Wendroth, Lund & Ponack*
ATTORNEYS

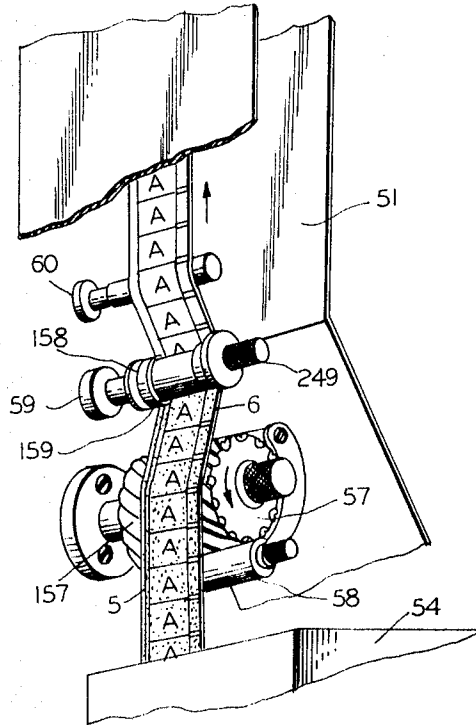


FIG. 13

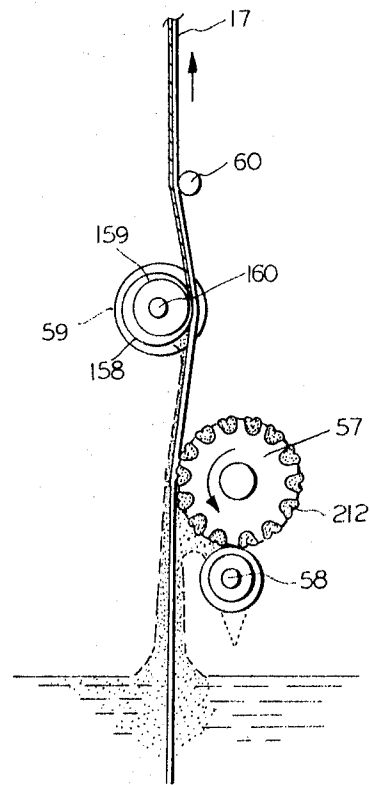


FIG. 12

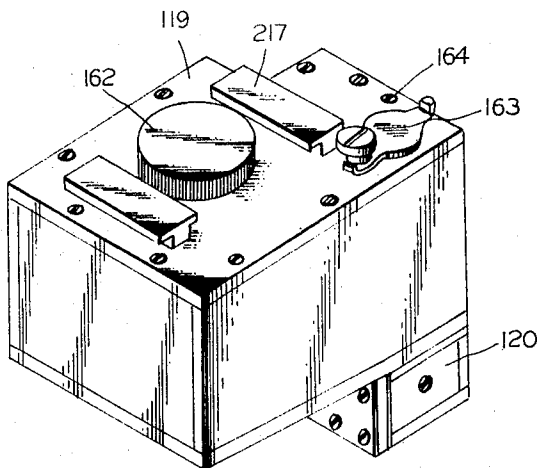


FIG. 14

INVENTORS
Y. HAYASHI
Y. YAMAMOTO
K. HIRAI
I. OTA

BY *Wendroth, Lind & Ponack*
ATTORNEYS

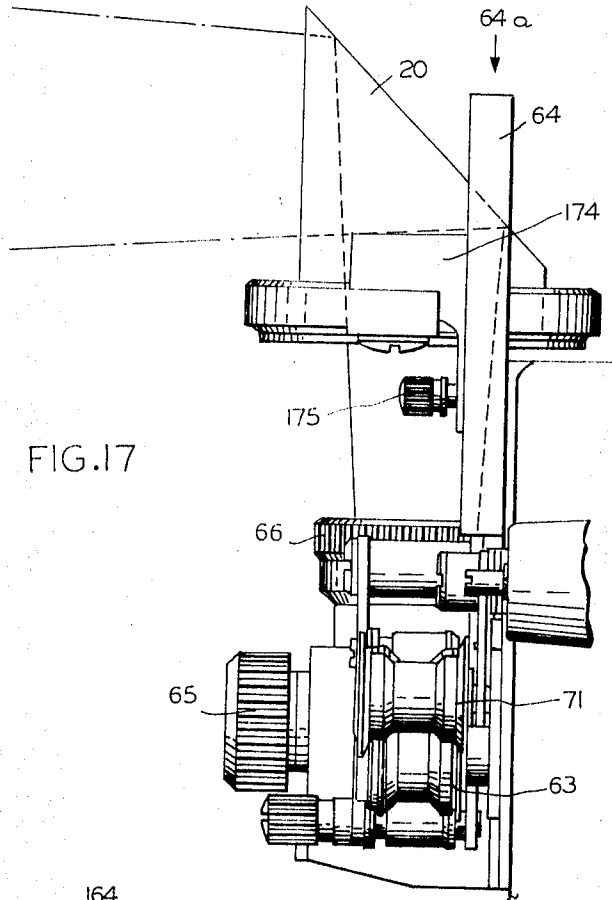


FIG. 17

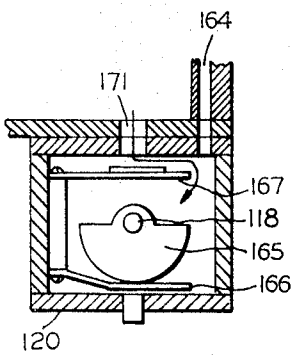


FIG. 15a

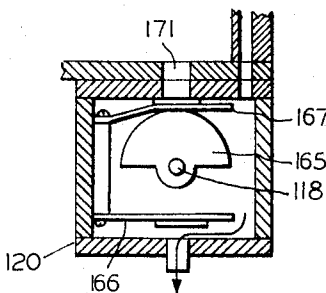


FIG. 15b

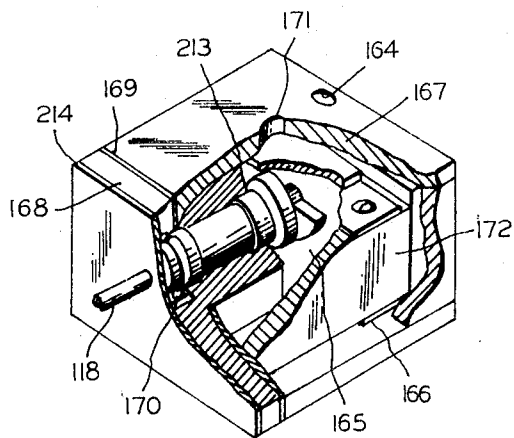


FIG. 16

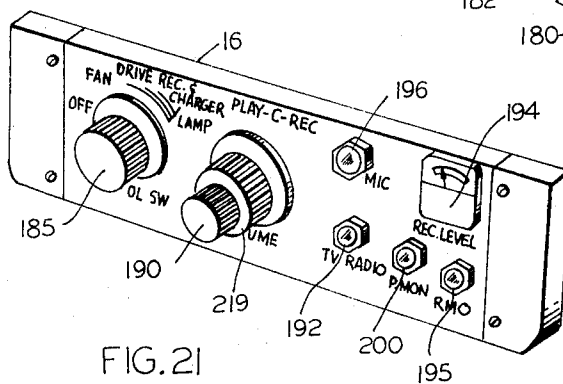
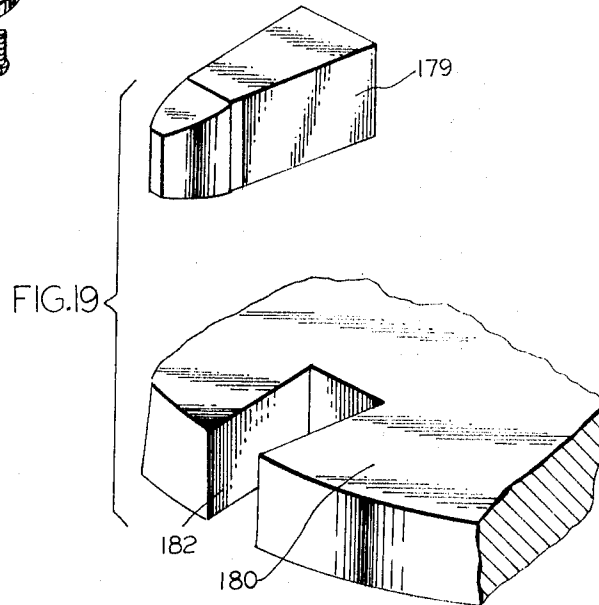
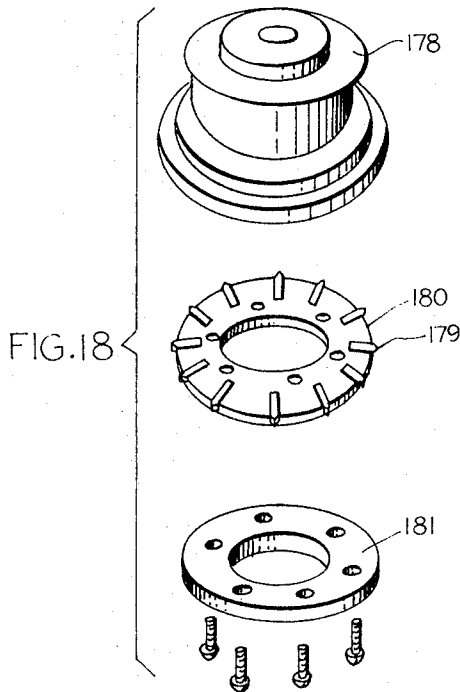
INVENTORS

Y. HAYASHI
Y. YAMAMOTO
K. HIRAI
I. OTA

BY

Wendroth, Lund & Bonack

ATTORNEYS



INVENTORS
Y. HAYASHI
Y. YAMAMOTO
K. HIRAI
I. OTA

BY *Wendworth, Lind & Ponack*
ATTORNEYS

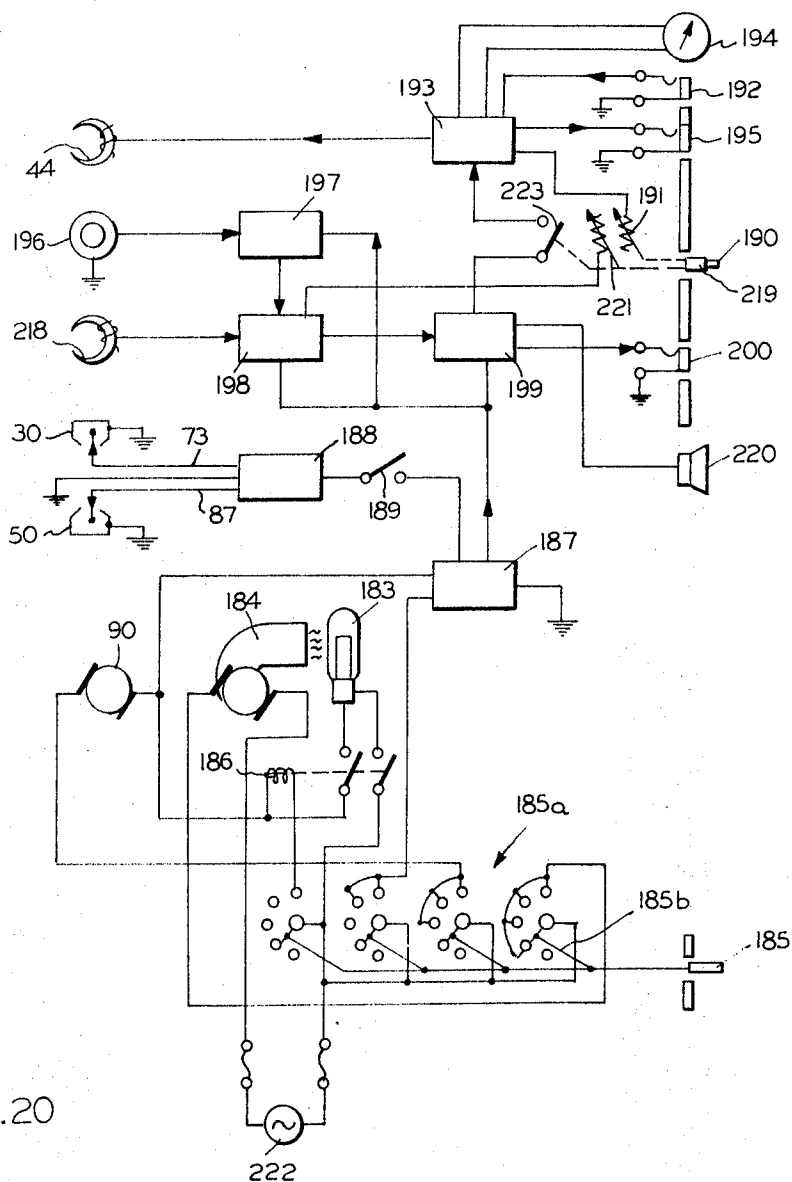


FIG. 20

INVENTORS
Y. HAYASHI
Y. YAMAMOTO
K. HIRAI
I. OTA

BY *Wendroth, Lund & Ponack*
ATTORNEYS

ELECTROPHOTOGRAPHIC MOTION PICTURE APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an image-recording and reproducing apparatus which records images on an improved transparent film by an electrophotographic process and which projects said images on an enlarged scale immediately after recording the images.

2. Description of the Prior Art

Various types of document copying apparatus, using an electrophotographic process, have been developed. Among them, copying apparatuses such as Xerox and Electrofax are well known. However, the sizes of the images produced by these apparatuses are practically the same as those of the original pictures. The prior electrophotographic processes have generally not been able to obtain a projected image which was magnified several hundred times or more. The prior electrophotographic processes have been inferior with respect to the resolution power, sharpness, and half tone quality of the recorded pictures as compared with the well-known silver halide photographic process.

The prior electrophotographic processes have an additional disadvantage in that the projected images contain dirty and foggy spots.

Many apparatuses and device have been known which record visible images and reproduce them on a screen on an enlarged scale. Much effort has been given to the magnification and reproduction of moving pictures from a television set. For example, a silver halide photographic process is now used at the broadcasting station. However, this method requires a large amount of apparatus for developing and requires a long time between the recording and the projection of the pictures. Moreover, it is impossible with this process to erase the images and to repeatedly reuse the film.

An ordinary diazo-photographic process forms a latent image on a photosensitive film comprising diazonium compounds. In a Kalvar-photographic process, a latent image is formed by exposing a photosensitive emulsion layer of diazonium compounds to light and is developed by heating said layer. These two photographic methods are characterized by a quick developing process and the fact that only a simple apparatus is required for developing. However, they have a drawback in that diazonium compounds are photosensitive in the near-ultraviolet region and are insensitive to the light of a cathode-ray tube, such as would be used in a conventional home television receiver. Moreover, it is impossible with these two methods to erase the image on the films and to repeatedly reuse the films.

A so-called "Photochromic film" comprises photochromic materials and is characterized by the ease of recording and erasing images. However, this film is photosensitive in the near ultraviolet region, and also is insensitive to the light of a cathode-ray tube.

A so-called "dry silver photographic film" is photosensitive in a visible wavelength and forms a latent image which is made visible by a simple thermal development. However, the film can not be used repeatedly by erasing the image deposited thereon.

An "Eidophor process" and a "Thermoplastic film process" are known processes for recording and projecting enlarged television pictures from a television set.

The Eidophor process, characterized by a simultaneous recording and reproduction of an enlarged image, can reproduce an enlarged image without a time delay, but can not preserve the reproduced images.

The "Thermoplastic film recording process" is based upon the bombardment of an electron beam onto a nonphotosensitive thermoplastic recording film and requires no fixing process. Said process is additionally characterized by a prompt development which is achieved by an incident heating,

but which has the disadvantage that the bombardment of the beam must be carried out in a vacuum.

SUMMARY OF THE INVENTION

5 An object of the present invention is to provide an electrophotographic motion picture apparatus capable of rapidly recording visible images and reproducing and projecting said visible images with a greatly enlarged form by utilizing a substantially flexible and transparent film which made it possible to produce fine visible images by an electrophotographic process.

10 A further object of the present invention is to provide an electrophotographic motion picture apparatus capable of simultaneously recording sounds and the corresponding visible images and of simultaneously reproducing said sounds along with greatly enlarged corresponding visible images.

15 A further object of the present invention is to provide an electrophotographic motion picture apparatus capable of recording visible images which are superior in their resolution, sharpness, and half tone quality.

20 A further object of the present invention is to provide an electrophotographic motion picture apparatus capable of recording visible images from the motion pictures on a cathode-ray tube of a home-use television receiving set.

25 Another object of the invention is to provide an electrophotographic motion picture apparatus capable of recording visible images and reproducing said visible images in a greatly enlarged form, said enlarged visible images being characterized by a few picture noises.

30 Said objectives can be achieved by an electrophotographic apparatus utilizing a substantially flexible and transparent film which comprises laminations consisting of, in the following order from the bottom up, a transparent adhesive layer, and an organic photoconductive insulating layer, and which further comprises a magnetic sound track on the back face thereof and running this film through an electrophotographic motion picture apparatus which comprises:

- 35 a. a film unwinding means for unwinding a roll of fresh film in a lighted place;
- b. means for continuously applying a uniform electrostatic charge by means of a first corona discharge device to said photoconductive top surface inside a dark space;
- 40 c. means for intermittently exposing said photoconductive top surface to a visible light ray image while the film is inside a dark space;
- d. sound-recording means for recording sounds on a sound-track on the film simultaneously with the exposure of said photoconductive top surface to the visible light ray image;
- 45 e. a second corona discharge device for providing said back face with an electrostatic charge having a polarity similar to that of the developer particles so as to prevent said developing liquid from being attracted to said back face;
- 50 f. developing means for continuously applying a dispersion-type liquid developer to said photoconductive top surface, while the film is inside the dark space, so as to produce visible images;
- 55 g. developer drying means for applying hot air exhausted from a cooling device for a projector lamp to the film outside of the dark space;
- 60 h. an image projecting means for projecting said visible images in the lighted place by means of a tungsten filament light at a rate of motion which is similar to the exposing or photographing rate aforementioned in (c);
- 65 i. means for reproducing the sound recorded on said sound track simultaneously with the reproduction of said corresponding visible images;
- 70 j. a winding means for winding the film containing said visible images and said recorded sounds; and
- k. film conveying means comprising guiding rollers, driving sprockets, claw mechanisms with aperture plates and developing rollers.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects of the present invention will become clear upon consideration of the following description taken together with the accompanying drawings wherein:

FIG. 1 is a perspective view partly in cross section, and on an enlarged scale, of a part of a flexible electrophotographic transparent film for use in the motion picture apparatus according to the present invention;

FIG. 2 is a perspective view of the motion picture apparatus of the present invention;

FIG. 3 is a front elevation view of the apparatus showing the apparatus with the cover of the dark space taken off;

FIG. 4 is a rear elevation view showing the driving system of the apparatus of the present invention;

FIGS. 5 and 6 are perspective views showing details of the corona discharge unit and of the film guiding unit of the first charging device, respectively;

FIG. 7 is a perspective view of the pulldown mechanism of the apparatus of the present invention;

FIG. 8 is a partial sectional view illustration of the photographic lens system of the apparatus according to the present invention and is taken on the horizontal plane including the incident light axis from an objective image;

FIG. 9a is a perspective view of a sound recording device which records sounds on the magnetic sound track on the back face of the film and FIGS. 9b and 9c are schematic elevation views showing the parts in different positions;

FIG. 10 is a perspective view of a second corona discharge device which prevents the developer particles from being attracted to the back surface of the film;

FIG. 11 is a perspective view, partly broken away, of a developing bath for use in the developing process;

FIG. 12 is a cross-sectional view of an applicator for controlling the thickness of the developing liquid attached to the front surface of the film and wipers for removing said developing liquid from the back face of the film;

FIG. 13 is a perspective view of the wiper shown in FIG. 12 showing grooves running obliquely thereof;

FIG. 14 is a perspective view of a reserve container for the developing liquid and a measuring box for supplying a constant volume of the developing liquid at a constant rate;

FIGS. 15a and 15b are cross-sectional views of the measuring box of FIG. 14;

FIG. 16 is a perspective view, partly broken away, of the interior of the measuring box of FIG. 15;

FIG. 17 is an elevational view, showing a projection lens and a rectangular prism, as shown in FIG. 3;

FIG. 18 is an exploded perspective view of a novel sprocket which forwards said film in the dark space of the apparatus of the present invention;

FIG. 19 is an exploded perspective view, on an enlarged scale, of a part of the plate and claw of FIG. 18;

FIG. 20 is a circuit diagram of the apparatus of the present invention; and

FIG. 21 is a perspective view of a control panel of the apparatus of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, reference character 1 designates a transparent base film made of any suitable and available material. A preferred base film is a cellulose acetate film having a thickness of from 100 to 150 microns or a polyethylene terephthalate film having a thickness of from 50 to 100 microns. A transparent, conductive layer 2 is superposed on said transparent base film 1 and acts as an electrode for charging a static charge onto a photosensitive top surface 4' when the film is kept in the dark or discharging the static charge from said photosensitive surface when the film is exposed to an actinic light. Preferred materials for making said transparent, conductive layer 2 are chromium, a nickel-chromium alloy, copper, cuprous iodide, gold, tin, tin chloride, titanium,

or titanium monoxide. It is necessary that said transparent conductive layer 2 have an electric surface resistance lower than 10^6 ohm/cm.² and a white light transmittance higher than 50 percent. For this reason cuprous iodide or titanium monoxide would be especially preferred since they form a thin film having a white light transmittance higher than 80 percent and a surface electric resistance lower than 10^5 ohm/cm.². Cuprous iodide is most suitable because it forms a thin film having a white light transmittance of between 85 percent and 90 percent and a range of electrical resistance between 10^3 and 10^6 ohm/cm.². A thin film made of cuprous iodide is characterized by only a slight variation in transmittance with a large variation in electrical resistance and it has excellent adhesive qualities for adhering to said base film 1. Said thin film 2, made of cuprous iodide, can be prepared in a way similar to that described in the U.S. Pat. No. 2,756,165.

Basically, said electrophotographic transparent film can be obtained by providing a transparent photoconductive layer 4 on a transparent, electrical conductive layer 2 without a capacitive insulating layer 3. However, said transparent photoconductive top layer 4, according to the present invention, is made of a polymer-type photoconductive material in order to increase its toughness, flexibility, and photosensitivity. As a result, said photoconductive layer 4 does not adhere readily to the transparent conductive layer 2. It has been discovered, in accordance with the present invention, that said polymer-type photoconductive layer 4 should be applied to a transparent capacitive insulating layer 3 because said transparent, capacitive insulating layer can be made highly adherent to both said transparent electrode 2 and said polymer-type photoconductive substance in the layer 4. Said transparent insulating adhesive layer 3 promotes the adhesion of the polymer-type photoconductive substance to said transparent electrode 2 and prevents the breakdown of the insulating effect of said polymer-type photoconductive substances in the layer 4 when the film is subjected to a corona discharge at a high voltage. The presence of said transparent adhesion layer 3 causes practically no impairment of the photosensitivity of the polymer-type photoconductive substance in layer 4. Said transparent adhesion layer 3 is made of a polyvinyl acetate resin or a vinyl chloride vinyl acetate copolymer resin having a thickness of from 3 to 10 microns. A preferred thickness of said transparent adhesion layer 3 is from 4 to 6 microns. This is achieved by coating said transparent electrode 2 with a solution of said polymer mentioned above. The electric resistivity, flexibility and adhesion of the surface of said transparent layer 3 is controlled by adding one or more plasticizers such as diethylphthalate, dioctylphosphate, or diphenyl chloride.

Said transparent adhesive layer 3 can be prepared by applying the following solution in a conventional and suitable manner, such as roll coating, doctor blade coating or bead coating.

EXAMPLE 1

	Parts by weight
60 Polyvinylacetate (AYAT resin made by the U.C.C. Co.)	100
Diethylphthalate	15
Saccharose acetate isobutylate	20
Toluene	600

EXAMPLE 2

	Parts by weight
65 Vinylchloride-acetate copolymer (VMCC resin made by U.C.C. Co.)	100
Diphenyl chloride	20
70 Saccharose acetate isobutylate	20
Methyl isobutyl ketone	100
Toluene	400

Care is required in the coating step to prevent the generation of bubbles, contamination due to dust, and unevenness of

the coated layer. The presence of such defects in said transparent adhesion layer 3 results in the transparent photoconductive layer 4 having a rough and scratched surface which prevents a uniform electrostatic charge from forming thereon and presents a satisfactory visible image from being reproduced without any noise. Even when said transparent photoconductive layer 4 is made smooth so as to cover said defects in the transparent adhesion layer 3, the defects are responsible for the abrupt changes in the electric resistance of the unexposed areas throughout the layers 3 and 4 and prevents a uniform electrostatic charge from being produced on the photoconductive layer 4.

Said transparent adhesion layer 3 has a thickness of between 3 to 10 microns and can easily be dried sufficiently so that is no longer tacky by applying a warm stream of air at a temperature of from 60° C. to 80° C. for 20 to 30 seconds. The purpose of the drying step is to prevent clouding of the interface between layer 3 and layer 4 which would occur if the layer 4 was placed on layer 3 which layer 3 was still wet. Said transparent photoconductive layer 4 is more strongly adhered to said transparent adhesion layer 3 when a solution containing a photoconductive material as set forth is Examples 3 or 4 is applied to said transparent adhesion layer 3 before it is completely dried.

Examples 3 and 4 set forth a suitable solution for applying to said transparent adhesion layer 3 so as to form said transparent photoconductive layer 4.

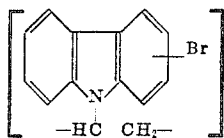
EXAMPLE 3

	Parts by weight
Brominated poly-N-vinylcarbazole (bromination degree; 100 mole percent).....	100
Polycarbonate (Makrofol, Bayer Co.).....	20
Diphenylchloride.....	30
3,6-dinitronaphthalic anhydride.....	1
2-(p-methoxystyryl)-3-phenyl benzopyrylium perchlorate.....	3
Dichloroethane.....	300
Monochlorobenzene.....	400

EXAMPLE 4

	Parts by weight
Brominated poly-N-vinylcarbazole (bromination degree; 100 mole percent).....	100
Polycarbonate (Makrofol, Bayer Co.).....	20
Chlorinated paraffine.....	20
1-nitroanthraquinone.....	10
Rhodamine B extra.....	0.05
Dichloroethane.....	300
Monochlorobenzene.....	400

The active photoconductive matrix in the solutions of Examples 3 and 4 is brominated poly-N-vinyl carbazole, which has the chemical formula:



This is mixed with polycarbonate, which has good compatibility with said polymer, in order to improve said polymer with respect to its brittleness so that the layer 4 is tough and flexible, Diphenyl chloride or chlorinated paraffine is added as a plasticizer in order to increase the flexibility of the layer 4. The photosensitivity of said polymer over a visible spectrum is increased by adding one or more sensitizer such as 3-6 dinitronaphthalic anhydride, 2-(p-methoxystyryl)-3-phenyl benzopyrylium perchlorate, 1-nitroanthraquinone, or rhodamin B extra, as shown in Examples 3 and 4. The electrophotographic sensitivities of the transparent photoconductive layer 4 resulting from the application of the solutions of Examples 3 and 4 were found to be 30 lux.second and 55 lux.second, respectively in E 1/2 which is a conventional ex-

pression of photosensitivity disclosed in the paper reported by Y. Hayashi et al. pages 1660 to 1670 of the Bulletin of the Chemical Society of Japan, 39, No. 9 (1966).

The solutions disclosed in Examples 3 and 4 can form a film having a thickness of between 5 to 25 microns and having a high transmittance of white light. Said layer 4, comprised of the photoconductive composition of Example 3 or 4, can be superposed on said transparent adhesive layer 3 by employing a conventional and suitable coating method similar to those of Examples 1 and 2. A preferred thickness of layer 4 is from 5 to 25 microns. A layer 4 having a thickness other than the preferred thickness is inferior in its miscellaneous electrical properties such as capacitance, photosensitivity, durability in a corona discharging atmosphere, resistance to insulation breakdown, and such other properties as light transmittance, flexibility, adhesion and coating characteristics. From an economic standpoint, a thinner layer 4 is more desirable. However, the requirements of durability under corona discharge and resistance to insulation breakdown require a thickness of more than 5 microns and preferably between 10 and 15 microns.

All of the ingredients of Examples 3 and 4 easily dissolve in aromatic solvents, such as benzene, toluene, xylene, and especially in halogenated aromatics such as monochlorobenzene and ortho-dichlorobenzene. The adhesion of the adhesive layer 3 is improved by being attacked by a solvent contained in the solution of the transparent photoconductive layer 4 during the coating. Therefore, it is important that the solvent in the composition of layer 4 swells or partially dissolves the ingredients of layer 3.

An organic photoconductive substance for application to the electrophotographic transparent film suitable for the novel apparatus of the present invention is a vinyl-type polymer having photoconductive groups arranged regularly at equal distances in its molecule chain. Said organic photoconductive substance has a higher photosensitivity than the conventional amorphous organic photoconductive systems comprised of an organic resin and an organic photoconductive substance of a lower molecular weight, such as an oxydiazole derivative (German Pat. No. 1,165,406), a triazole derivative (U.S. Pat. No. 3,112,197), an acylhydrazone derivative (U.S. Pat. No. 3,066,023) or a leuco-triphenylmethane derivative (U.S. Pat. No. 3,168,857). The photoconductive layer 4 in accordance with the present invention has had its photosensitivity improved by the inclusion of brominated poly-N-vinylcarbazole and its toughness improved by the inclusion of a polycarbonate additive.

The photoconductive material used in the present invention has aromatic rings which are provided with a large number of π electrons and form a charge transfer complex having a high photoconductivity in association with an electron-acceptor type sensitizer. For example, brominated poly-N-vinylcarbazole is an electron-donor and forms a charge transfer complex with 3,6-dinitronaphthalic anhydride or 1-nitroanthraquinone, which acts as the electron-acceptor. The photoconductive layer 4 having the compositions shown in Examples 3 and 4 has an electric resistivity lower than 10^3 ohm-cm. at a light exposure of 100 lux.second as compared to its resistivity in the dark. The time constant of said photoconductive material is less than 0.02 seconds with respect to the variation in the electric resistance in response to the light. When one takes photographs, of the pictures on a cathode-ray tube of an ordinary television set, suitable for home use, which has a brightness of 300 foot lambert in the highlight portions, with a motion picture camera at a lens-aperture of $f=1.8$ and at a rate of 24 frames per second, it can be shown experimentally that each of said frames is subjected to a light exposure of 100 lux.second which is adequate for said photoconductive layer 4 to form a clear latent electrostatic image. Such highly photosensitive electrophotographic transparency makes it possible to practice the motion picture apparatus in accordance with the present invention.

The electrophotographic motion picture apparatus according to the present invention is designed to record and reproduce sounds as well as motion pictures. The recording and reproducing of sounds can easily be achieved by providing the film with a magnetic coating. Said magnetic recording forming a sound track 5 can be made by applying a dispersion layer having a magnetic powder such as γ -hematite in a binder solution along one side of the back face of the film. The composition of the conventional magnetic sound track is designed to be capable of recording and reproducing sound for an audio tape recorder, a video tape recorder of the sound apparatus for motion pictures produced on the conventional silver halide, photographic film. It is required, in accordance with a corona discharge ion atmosphere and in a developing liquid after the film is exposed. It is therefore required that the sound track 5 be tough enough to resist electrical and chemical damage.

For these reasons, the composition of the material forming the sound track 5 does not contain any ingredient which would be oxidized by the ozone generated during the corona discharge, nor does it contain anything which would cause it to swell during developing or be impaired by the solvent in a developing liquid. It is also necessary that the composition of the sound track 5 does not dissolve into the developing liquid, because the dispersion of the developing particles would be impaired by such dissolution. The following example is of a suitable composition for the sound track 5:

EXAMPLE 5

	Parts by weight
γ -hematite.....	100
Polyvinylacetate.....	35
Polyurethane resin:	
(Desmodul L, Bayer Co.).....	10
(Desmophen 51100, Bayer Co.).....	8
Methylethyl ketone.....	140
Methylisobutyl ketone.....	70
Methoxy acetate.....	70

Said composition is mixed well for a day or more in a ball mill. The mixture so produced is then applied to both side edge portions of the back face of the film, as shown in FIG. 1.

One strip of the magnetic coating is a magnetic sound track 5 and the other strip 6 is used for equalizing the thickness at the opposite sides of the film. The sound track 5 can be applied by a well-known conventional method such as bead coating, gravure printing, knife coating and roll coating. The thus produced track layer adheres strongly to the substrate and has a high resistance to wear caused by the friction between it and the magnetic head.

A film provided with layers 2, 3, and 4 and a magnetic sound track 5 is cut to a predetermined width and is provided with perforated holes at predetermined distances so as to form a motion picture film suitable for use with the electrophotographic apparatus of the present invention.

MOTION PICTURE APPARATUS

Referring to FIG. 2, a film 17, prepared in accordance with the present invention, is forwarded from a supply reel 8 and is exposed to light in a dark space, comprised of a predark room, a main dark room and a post-dark room, and having a cover 9, by means of a photographic lens (not visible), so as to form a latent electrostatic image thereon. The finder 10 is a monitor for adjusting the focus of the image produced on said film. The latent image is developed by a liquid developer. The film passes through a projection unit 12 where light is passed through it from a light in a lamp housing 13; it then passes through a sound regeneration unit 14 and finally is wound up around a takeup reel 15. A control panel 16 contains the control members for the electrical circuits illustrated in FIG. 20.

The motion picture apparatus can be operated by means of the control panel 16 after fresh film 17 is loaded in the apparatus in a predetermined manner, as shown in FIG. 3. For

example, a latent electrostatic image printed from a picture on a cathode-ray tube 18 is electrophotographically converted into a visible image at the dark room portion and is immediately projected on the screen 19 by the projection system 12 (FIG. 2). The light path of a projected image is reflected to the left by a rectangular prism 20. An image in a reflected form can be prepared by removing the rectangular prism 20 of the projection system 12 and the image can be projected towards the left side of FIG. 3 in the direction of the front of the apparatus. After a film has been projected, it can be stored by winding it up on a takeup reel 15.

GENERAL ARRANGEMENT

Referring to FIG. 3, a fresh film 17, wound around a supply reel 8, passes over a tension roller 21 and enters a predark space 23 through an opening 22 and, after passing over rollers 24 and 25, goes into a main dark space 27 through an opening 26. While traveling between a roller 28 and a roller 29, the film has the surface electrostatically charged by a first corona discharge device 30. The film then enters an exposure system 32 being driven by sprocket wheel 31.

Said exposure system 32 comprises a photographic lens 33, a rotating shutter 34 (the details of which are not shown since they are conventional), a pulldown mechanism 35 with a film aperture plate, a pressure plate 36, which presses against the back face of the film, and an optical unit 37 for monitoring the image reproduced on the film. A lens 10 (FIG. 2) is the ocular lens of said optical unit 37. The axis of the light rays is reflected to the left at a 90° angle by a mirror 38 (FIG. 8) so as to make it possible to monitor the image from the front of the apparatus. The sprocket 31 is coupled to a film driving means for driving the film from the reel 8 to the entrance of the exposure system 32. Said pulldown mechanism 35 gives to the film an intermittent movement by employing a triangular cam mechanism which is well known in the prior art.

Referring to FIG. 7, the film is stopped at the photographing position by the pulldown mechanism 35, and is exposed to the light from the objective image through an opening in the rotating shutter, which rotates at a constant speed in association with said pulldown mechanism 35, and then is pulled downward by claws 101 and 101' of said mechanism 35 when the shutter is closed. The exposure time will be explained for the particular case where television pictures are reproduced on the film, in accordance with the invention. It is required that a given frame of the film be exposed for a time which is larger than the time the respective frame of the cathode-ray tube of the home use television set is exposed by an amount of time which is an integral number times the time the frame of the cathode-ray tube is exposed. Stated mathematically, the exposure time E is as follows: $E = (1/f) n$ where f is the number of frames per second exposed on the cathode-ray tube and n is an integer. This is necessary in order to obtain a reproduced image having uniform brightness. For example assume that television images are produced at a rate of 30 frames per second on a cathode-ray tube. In such a case, each frame of the film must be exposed for a time larger than 1/30 second by an integral number times 1/30 second. When the motion picture apparatus, according to the present invention, has a conventional photographic speed of, for example, 24 frames per second, the aperture angle of the rotating shutter should be $288^\circ (=360^\circ \times 24/30)$ in order to obtain a picture-frame which is uniformly exposed.

Referring again to FIG. 3, after latent electrostatic images are produced on the film it is forwarded at a constant speed by a sprocket 39 to a sound drum 40 where it is subjected to the recording of sounds. The drum 40 rotates smoothly in such a way that the balancing rollers 41 and 42 apply a constant tension to the film. The drum 40 is prevented from rotating in a discontinuous manner by a fly wheel 43 which is mounted on the extended axle of the drum 40 (FIG. 4). A discontinuous rotation of the drum 40 would result in wow and flutter in the recorded sounds. A magnetic recording head 44, positioned

within the drum 40 (FIG. 9) contacts the sound track 5 of the film in order to record the sounds. A pressure roller 45 attached to a lever 150 applies pressure to the film designed to maintain a good contact between said sound track 5 and said magnetic head 44. In the case of recording from a television set suitable for use in the home, the input of the sound signal can be obtained by branching the output of the sound reproduction circuit of the television set as will be described in connection with FIG. 20.

The sound is recorded on said film at the sound drum 40 while the corresponding latent image is recorded at the exposure unit 32. The distance between the pressure roller 45 and the exposure unit 32 causes the film to have a discrepancy in the position of the recorded picture and the corresponding recorded sound. Therefore, in order to simultaneously reproduce the pictures and the corresponding sounds, it is necessary to take this discrepancy into consideration. The distance along the film between the standstill position 46 of the projection unit and the contact point of the pressure roller 47 of the sound reproducing unit is the same as the distance between exposure unit 32 and sound drum 40.

The back face of the film, containing the recorded sounds, passes beneath a second corona discharge device 50 which is mounted on an arm 49 bearing against a sprocket 48, and which generates ions having an opposite polarity to those applied to the front surface of the film. These ions make the back face of the film oppositely charged from the front surface of the film. Due to Coulombic repulsion, said charge prevents developer particles from adhering to the back face during developing.

The film, having the latent images formed on the surface thereof, and the sound track recorded on the back face thereof, goes through an opening 53 to a post-dark space 52 which is separated from dark space 27 by a partition 51 and which contains all of the necessary parts of the developing unit. The partition 51 acts as a protecting wall which prevents stray light and vapor from the developing bath 54 from entering the main dark space 27.

It is required that the liquid developer used in the apparatus according to the present invention have the following characteristics: (1) the carrier medium therefor must be quite volatile, not inflammable and not toxic; (2) the pigment thereof must be in the form of a fine powder suitable for producing micro images; and (3) the dispersion thereof must have a long shelf life.

Preferred compositions of said developer are shown in the following examples.

EXAMPLE 6

	Parts by weight
Trifluorotrichloroethane.....	100
Colloidal graphite (Oildag, Acheson Ltd.).....	0.05
Cobalt naphthenate.....	0.006

EXAMPLE 7

	Parts by weight
Trifluorotrichloroethane.....	100
Fine magnetite powder.....	0.1
Cobalt naphthenate.....	0.005

EXAMPLE 8

	Parts by weight
Trifluorotrichloroethane.....	100
Colloidal graphite (Oildag, Acheson Ltd.).....	0.04
Fine grain titanium dioxide powder.....	0.02
Cobalt naphthenate.....	0.005

In the above three Examples, trifluorotrichloroethane serves as an insulating medium which is quick drying and which is not flammable. The colloidal graphite, magnetite powder, or titanium dioxide powder serves as the pigment, and the cobalt naphthenate serves as a charge controlling agent which controls the charge polarity of said pigment parti-

cles and which gives a single polarity, i.e. positive polarity, to all of the pigment particles. The pigment deposited to bring out the latent electrostatic image can easily be erased by wiping the film mechanically, thus preparing the film for reuse.

A preferred method of permanently preserving the fixed images involves adding to the liquid developer a small amount of a binding resin such as polystyrene resin or chlorinated terphenyl resin which thoroughly dissolves in said medium and which does not lower the electrical resistivity of the medium or the dispersing activity of the liquid.

The film passes over rollers 55 and 56 in the developing bath filled with the developing liquid and moves upward toward the wiper 57. The density of the images is determined by: (1) the discharge voltage of said corona discharge device 27; (2) the *f* number of the photographic lens; (3) the concentration of the developing particles in the developing liquid; and (4) the immersion time in the developing liquid. When the discharge voltage and the *f* number are predetermined, the highest density of a visible image corresponds to that amount of deposited developing particles which is necessary to make the coulombic force of the latent image zero. Said amount can be deposited by immersing the film in the developing liquid until no more particles adhere to the film regardless of the concentration of the particles in the developing liquid. However, the film path through the developing bath is not sufficiently long to permit the maximum number of developing particles to adhere to the film. That is, the immersion time is limited by the physical arrangement of the apparatus. In addition, it is known that rich half tone images can be obtained by immersing the latent images in a relatively dilute developing liquid for a relatively long period of time. Therefore, the developing bath according to the present invention is not designed to complete the developing process, but rather, is designed to adhere the developing particles uniformly to the latent images in an initial developing process.

Developing liquid attaches to both surfaces during developing, and said liquid is still attached as the film leaves the bath 54 and rises toward the wiper 57. The amount of the developing liquid is dependent upon the viscosity, the specific gravity, and the surface tension of the developing liquid, and the running speed of the film. The developing liquid attached to the back face of the film is removed by a wiper 57, the surface of which, in contact with the film, rotates in a direction opposite to the direction of movement of the film. The removed liquid is squeezed from the wiper 57 by a squeezing roller 58 and falls into the developing bath 54, as shown in FIGS. 12 and 13. The developing particles are charged so as to have the same polarity as the back face of the film, and, therefore, most of said particles are transferred to the wiper 57 together with the medium for the developing liquid.

The thickness of the coating of the developing liquid attached to the front surface of the film is adjusted by bringing the film into contact with a stationary applicator 59 so as to remove the excess developing liquid. The film with the liquid removed moves vertically upward past a fixed roller-type squeezer 60, which contacts the back face of the film, and completely removes any remaining liquid from said back face.

The developing process is completed when the film reaches the upper vertical portion of the post-dark space 52 and the film leaves the post-dark space 52 after passing over roller 61 which changes its direction of movement from the vertical to the horizontal plane. The film then passes through a box 62 through which the air used for cooling the tungsten lamp (not visible in FIG. 3) of the projection means is discharged. The temperature of said exhausted air is from about 50° to 60° C. The residual carrying medium for the developing liquid, which is left on the upper surface of the film, is completely dried by the hot air, thus leaving only dry images on the film. When the developing liquid contains a fixing agent, the fixing agent is cured as a result of its contact with the warm air. Thus, the drying process, consisting of passing the film between the roller 61 and the tension roller 71, results in a film which is permanently fixed.

The film containing the dried images is then forwarded at a

constant speed to a sprocket 63 where it is subjected to an intermittent motion by a pulldown mechanism 46, similar to the one used during the photographing process, resulting in the projection of the visible images. The projecting optical unit 12 comprises a convex projecting lens system 66 and a rectangular prism 20 having an optical axis which coincides with that of the convex lens system 66. The prism 20 is designed so as to be adjustable sideways in the horizontal plane by sliding it along a slider 64. The focus of said lens 66 is adjusted by a knob 65. A lamp serving as a light source is positioned in the lamp housing 13 and cooled by subjecting it to the forced air from an air fan (not visible) which is attached to the back face of the apparatus. The cooling air is exhausted to said small box 62, mounted on said lamp housing 13, and the light from the lamp is projected onto the film surface through a condenser lens (not shown).

A sound track, upon which sounds are recorded simultaneously with the recording of visual images but at a position a predetermined distance ahead of where said visual images are recorded, contacts a magnetic head under the pressure of a pressure roller 47 attached to a pressure lever positioned below the sound drum 67, and reproduces the sounds simultaneously with the reproduction of the visible images. The sound signal is amplified by an audio amplifier and is then transferred to an external loud speaker. The sound reproduction can be achieved by employing a magnetic head, a drum, a pressure roller, and a pressure lever, similar to those employed in recording the sound.

After the projection of the visible images and the reproduction of the sounds, the film is forwarded by a sprocket 68 around rollers 69 and 70 and wound upon a takeup reel 15. Said takeup reel 15 is frictionally driven by the friction between the pulley 135 and the pulley 136 (FIG. 4) and winds the film under adequate tension.

When the apparatus is to be used for projecting a printed film already containing a sound track, the recording and developing apparatus can be bypassed and the film can be fed directly from the supply reel 8 to tension roller 71 and then directly to the projection and the sound reproduction apparatus.

DRIVING SYSTEM

Referring to FIG. 4, a main shaft 92 is supplied with a driving force by a driving belt 91 from a synchronous motor 90 mounted on the main frame of the apparatus. The parts of the driving system positioned at one end of said shaft 92 are for driving members for the dark room apparatus and the parts of the driving system positioned at the other end of said shaft 92 are for the driving members for the projection mechanism (FIG. 2).

A gear 94, positioned on a driving shaft 95, is meshed with a gear 93, mounted on the shaft 92, and causes said shaft 95 to rotate at the same speed as shaft 92. Said shaft 95 is the main driving shaft for the rotating shutter 34 (not shown in FIG. 4), the pulldown mechanism 35, and the sprockets 31, 39 and 48 (FIG. 3). Referring to FIG. 7, a shaft 98, driven by a shaft 95 (FIG. 4) through gear 96 on shaft 95 and gear 97 on shaft 98, serves as the axle of the triangular cam 99. Said triangular cam 99 causes claws 101 and 101', attached to a frame 100, to move up and down in accordance with the up and down movement of said frame 100. A grooved cam 103, positioned coaxially with the shaft 95, causes the frame 100 to carry out a reciprocal swinging movement about the shaft 104. Consequently, claws 101 and 101' are subjected to a rectangular movement and engage in the perforations of the film and pull the film down.

Referring again to FIG. 4, the rotating speed of a worm wheel 106 is reduced by a worm 105, positioned on the shaft 95, while a gear 108 is rotated at a constant speed by an idler gear 107 in mesh with gears 106 and 108 in the same direction as wheel 106. Said worm wheel 106 and said gear 108 are on the same shafts as sprockets 31 and 29 (FIG. 3), respectively, and drive said sprockets 31 and 39. A shaft 111, driven by

gear 109 in mesh with gear 106, and gear 110 in mesh with gear 109, is the driving shaft for the sprocket 48 (FIG. 3) and rotates at the same speed and in the same direction as the worm wheel 106. A pulley 113, on the same shaft as the wiper 57 (FIG. 3), is rotated at a reduced rate of speed by means of a belt 205 around a pulley 112 which is on the same shaft as the gear 110, so as to drive the wiper 57. A shaft 116 extending crosswise to the axial direction of the shaft of the worm gear 115 is driven at a reduced speed by the worm gear 115 in meshing engagement with the worm 114, which in turn is coaxial with and driven by gear 108. A shaft 118 is connected to the shaft 116 by means of a universal joint 117. Said shaft 118 is the shaft for a cam which is contained in a measuring box 120 attached to the container 119 which is used for storing the developing liquid, as shown in FIG. 14 and FIG. 15.

The following description will describe the driving system between the main shaft 92 and the projection mechanism. A shaft 123, rotated at the same speed as shaft 92 by means of meshing gears 121 and 122 on the respective shafts, is the main driving shaft for the projection system. Said shaft 123 carries a rotating shutter 124 for the projection apparatus, a pulldown mechanism 46, and a worm 125. The shaft 123 rotates at the same speed as the shaft 95. The shutter 124, the pulldown mechanism 46, and the worm 125, are, respectively, the same as the shutter 34, the pulldown mechanism 35 and the worm 105. Similarly, the worm wheel 126, the gear 128 and the gear 130 are respectively the same and rotate at the same speed as the worm wheel 106, the gear 108 and the gear 110. Worm wheel 126 drives sprocket 201, gear 128 driven from gear 126 through idler gear 127, drives sprocket 63, and gear 130 driven from gear 126 through idler gear 129 drives sprocket 68 (FIG. 3).

A pulley 132 is on the same shaft as a gear 131 and is meshingly engaged with the gear 130 which is connected to the sprocket 68, and drives the film-rewinding means. The force for driving said rewinding means is supplied by means of a belt 133 from a pulley 132 to a pulley 135 which is contained in a rewinding arm 134 positioned on the outside of the casing of the apparatus. A pulley 136 on the same shaft as the pulley 135 and in frictional engagement therewith supplies the driving force to a pulley 138 by means of a belt 137. Said pulley 138 is on the same shaft as the takeup reel 15. The pulley 136 rotates under the bias of a pressure plate (not shown) which applies a frictional force to said pulley 136. When a film roll wound around the reel 15 has a large diameter which results in a large tensional force imparted to the film itself, the pulley 136 rotates with respect to the pulley 135 so as to provide the film with an adequate tensional force.

CHARGING DEVICES

Referring to FIG. 5, which is a bottom perspective view, a high DC voltage of about 4 to 7 kv., supplied by means of a cable 73 from a high voltage source 188 (FIG. 20), is applied to several tungsten wires 75 which have a diameter of 10 to 30 microns and which are connected between a pair of metal plates 74 so as to generate a corona around said wires. The connections between said metal plates and said tungsten wires are achieved by employing an electrically conductive paint. It is necessary that the supports 76 for the plates 74 and the end supports 77 be made of an insulating material such as polystyrene resin, polyacetal resin or polymethyl methacrylate resin. An upper plate 78, made of a metallic material, is grounded by connecting it to the body of the apparatus. Mounting tabs 208 are provided on end supports 77. The surface of said film is uniformly charged as the film runs through said charging unit at a constant speed. However, if the entire surface area of the film is charged, it causes the developing particles to adhere to both sides of the film, as well as to the image area, during the developing process. Said developing particles, which adhere to the sides of the film, contaminate the rollers, sprockets, claws of the pulldown mechanisms and aperture plates with which the film comes into contact. In ad-

dition, if the film is loose when it runs through the charging apparatus, it will touch the fine wires of the corona discharge device snapping said wires. These disadvantages can be eliminated by providing a film passing guide 72 (FIG. 3), as shown in FIG. 6. The film passing guide is designed such that the film passes beneath two plates 79 which are spaced from each other by a distance which is 1.0 mm. greater than the width of an image frame. The plates 79 are mounted on the body of the apparatus by means of L-shaped angle stays 80. A slight pressure is applied to said plates 79 by means of a pressure plate 81, having a groove 81a therein which is slightly deeper and wider than the thickness and the width of the film, respectively, in order to provide a smooth running channel for the film and to prevent the film from shifting in any direction. The plate 81 is biased toward plates 79 by coil springs 82 positioned around two bolts 82a mounted on mounting plate 83. The film is easily placed between the pressure plate 81 and the upper plates 79 by pushing down mounting plate 83 and the pressure plate 81. Plate 83 is pivotally mounted on the apparatus by bolts 84 and can be spring loaded. This arrangement provides that both side edges of the film are in contact with a conductive plate and therefore are not charged by the corona discharge device. In addition, because of the slight clearances between the running film and the guiding device, the film is smoothly forwarded without contacting the corona wires.

A further corona generator is provided which gives to the back face of the film a charge opposite to that given the front face of the film in order to prevent developing particles from adhering to the back face of the film. The further corona discharge device can be installed anywhere in the dark space 27 to the point where the developing process takes place (FIG. 3). It is preferable to install it just before the point where said developing process takes place. A small box 50 for holding the further corona discharge device is mounted close to the developing bath on an arm 49 bearing against the sprocket 48 (FIG. 3) in accordance with the present invention. Because the back face of the film is charged opposite to the charge of the front face in order to prevent the developing particles from adhering to said back surface, said back surface is satisfactorily charged by a charge intensity smaller than that used for charging the front surface of the film. Therefore, the second discharge device, positioned on the arm 49 which bears against the sprocket 48, is half or one-third the length of the first discharge device. FIG. 10 shows the sprocket 48 which has claws for forwarding the film 17 in the direction of the arrow, the pressure arm 49, the discharge unit 50 mounted on the pressure arm 49 and including an external casing 85 which serves as a grounded electrode, supports 86 made of a plastic insulating material, a cable 87 for supplying a high voltage and wires 88 upon which a corona can be generated. The second discharge device 50 for generating corona ions opposite in polarity to those deposited on the upper surface is substantially the same in construction as the first discharge device 30 but differs in size. The arm 49 is rotatably mounted on the shaft 89 thus making it easy to position the film on the sprocket 48. However, said discharge device moves up and down in accordance with the movement of the arm 49 and for this reason, the cable 87 must be relatively flexible. A voltage opposite in polarity to the negative polarity supplied to the discharge wires 75 (FIG. 5), is supplied to the discharge wires 88. It is convenient in designing the high voltage circuit to make the amplitude of both equal.

EXPOSURE AND RELATED SYSTEMS

The exposure system of the apparatus according to the present invention, comprises a photographic lens system, a pulldown mechanism including a rotating shutter and an optical finder system. The photographic lens system and the film

pulldown mechanism can be constructed in a manner similar to those known in the prior art. The film pulldown mechanism was previously described in detail (FIG. 7) and is omitted from the following description.

Referring to FIG. 8, a photographic lens 33 is designed to project a real image onto the surface of the film 17 by focusing the image light, coming from the objective image, through the frame opening 140 of the aperture plate 139 (FIG. 7). A large quantity of said light passes through the transparent film and continues on through the frame opening 142 of the pressure plate 141 to an objective lens 216 of the ocular system 37 and eventually to a mirror 38. The light is reflected off of the mirror and after traveling along tube 203 reaches the human eye through the ocular 10. The optical system of the finder is designed so as to have a fixed focus at the film surface. Since undesirable light would enter the apparatus at the ocular 10, it is necessary to keep the ocular covered with a cap in order to prevent stray light from entering when said ocular 10 is not being used for observing the image.

Said finder system according to the present invention has an insured focus adjusting system which is brought about by employing the substantially transparent film in accordance with the present invention. There is no parallax between the images on the finder and the real images on the film. It is difficult for the conventional silver halide film to achieve such focus adjusting because the emulsion layer on the undeveloped silver halide film prevents light from passing through it.

SOUND RECORDING AND SOUND REPRODUCING DEVICE

Referring to FIGS. 9a-9c, the film 17, containing the latent images, passes between the drum 40 and the balancing roller 41 and is wound around the drum 40 with the photosensitive surface thereof facing upward. A reduced diameter portion 143 is provided along one edge of drum 40 in order to prevent wow and flutter from being caused by the perforations along that side of the film coming into contact with the drum 40. The magnetic sound track 5 is applied on the right side of the back face of the film as viewed in the running direction, i.e. the back face of the portion of the film seen in FIG. 9a. The magnetic head 44 is positioned in the path of the track 5 so as to come into contact with the entire surface area of the track 5. The head 44 is secured to a frame 145. The knob 147 can be lifted upwardly in the direction shown by the arrow 147a and the other end of the lever 146 on which knob 147 is mounted rotates about the shaft 224 in the direction of the arrow 146a. The other end 146b of lever 146 rotates in the direction of arrow 146c and engages the one end of lever 148 mounted on shaft 149 to pivot lever 148 and shaft 149 to the positions of FIG. 9b. This causes a lever 150 fixed to the shaft 149 to rotate counterclockwise, and the right-hand end of frame 145 to rotate downwardly, and the left end of frame 147 to swing upwardly in the directions shown by the arrows 150a and 150b so as to move the pressure roller 45 away from drum 40 and the recording head 44 away from the back face of the film, respectively.

The sound reproducing device according to the present invention employs the same type of mechanism as that described above for the sound recording apparatus. The pressure roller, known in the prior art, was shaped to press down the entire width of the film surface, while the pressure rollers according to the present invention touch only the side areas of the film in order not to damage the electrostatic latent images or the deposited developer particles forming the visible images. It is necessary that the roller 45, used in the sound recording unit, be made of an insulating elastic material such as buthyl rubber.

DEVELOPING DEVICE

Referring to FIG. 11, the film is forwarded around the rollers 55 and 56, which are mounted on arms 55a and 56a, so as to pivot about the axles 151 and 210, respectively, in the

direction shown by the arrows 55b and 56b so as to make it easy to position the film along the proper path in the developing bath. When the knob of the lever 153 is rotated in the direction of the arrow 153a along the rail 154, the roller 55 is lifted in a direction shown by the arrow 55b. The lever 153, held on the rail 154 by a spring 155, can be held at any position along the rail 154. The rollers 55 and 56 have small stirring means 156 to stir the developing liquid uniformly.

FIG. 12 is a cross-sectional view illustrating the wet film being acted on by the wiper 57 in contact with the back surface of the film in order to remove the developing liquid present on said front surface. The wiper 57 has grooves 212 obliquely cut in the periphery thereof, like a spiral gear. Said grooves are filled with soft cloth which absorbs the developing liquid. When a wiper having rectangularly cut grooves is used to wipe off the developing liquid, the film is left with discontinuous stripes as a result of the eccentric contact between the film and the wiper. Such undesirable stripes can be eliminated by employing a wiper having obliquely cut grooves in accordance with the present invention. Referring to FIG. 12 and FIG. 13, a supporting surface 158 of the applicator 59 is in contact with both side areas of the film and is in an eccentric relation with a doctor surface 159 so that the applicator 59 can control the amount of developing liquid on the front surface of the film by having its rotational position adjusted in accordance with the concentration of the developing liquid. The center of the cylindrical doctor surface 159 is coaxial with the axle 160 of the applicator 59. The axle 160 has an adjusting screw (not shown) thereon for fixing the position of the applicator 59. The applicator 59 is positioned depending on the concentration of the developing liquid and the running speed of the film. A small wiper 60 in the form of a finely polished stainless steel bar having a circular cross section is positioned similarly to the applicator 59 with respect to the film path. The small wiper 60 wipes off the residual liquid which is not completely removed by the main wiper 56 and, also, the liquid which has penetrated through the perforations to the back surface of the film during scraping of the excess liquid attached to the front surface of the film by the applicator 59. If the applicator 59 (FIG. 12) is omitted, an excess of developing liquid remains on the film over and above the amount containing developing particles equivalent in the electrostatic quantity to the latent images. Said excess of developing liquid, when dried, forms dirty spots on the visible images recorded on the film. The developing process continues after the film passes through the applicator 59, as described above. The applicator 59 controls the amount of the developing liquid which is applied to the latent image during the developing process in accordance with the concentration of the developing liquid, that is, the number of the developing particles in a unit volume of developing liquid.

The total volume of developing liquid in the bath decreases as the developing process progresses and likewise varies with respect to its composition due to the selective attachment of the pigment to the surface of the film and to the evaporation of the medium in the developing liquid. It is desirable to keep the amount and the composition of the developing liquid in the bath constant during the operation of the electrophotographic process of the present invention.

Referring to FIG. 14, a reservoir 119 for supplying liquid is positioned over a measuring box 120 so as to supply the liquid to the developing bath 54 by a gravitational force. Said reservoir 119 is mounted on the back face of the apparatus within the casing. The reservoir 119, according to the present invention, is secured to the apparatus body on sliding rails 217 which serve as supports. A knob 162 is positioned such that when it is unscrewed, it presses against the body of the apparatus, thus locking the reservoir in place. The supply of liquid in the container is replenished through a hole which is covered by a cap 163. A hole 164 is provided to serve as an air opening for maintaining atmospheric pressure within the measuring box 120.

Prior to determining what the concentration of the liquid and the volume of the measuring box should be, it is necessary

to determine the rate at which the developing liquid decreases during the developing process and also the rate at which the medium evaporates. The amount it decreases can be compensated for by supplying the liquid of predetermined concentration from the reservoir 119. In FIG. 15a, as indicated by the arrow, liquid is being supplied to the measuring box 120 when a cam 118 presses a lower valve 166 to close it and releases an upper valve 167 to permit it to open. After the measuring operation is finished, the cam 118 causes the upper valve 167 to close, thus preventing any more liquid from flowing into the measuring box and permits the lower valve 166 to open allowing liquid to flow out of the box, thus replenishing the amount of liquid in the developing bath 54, as shown by the arrow in FIG. 15b.

Referring to FIG. 16, an end plate 168 can be removed in order to provide access to the interior of the measuring box. A gasket 169 prevents the liquid from leaking when the plate 169 is fixed to the body. A shaft 118 for the cam 165 extends through the plate 169 and has an O-ring 170 therearound which prevents the liquid from leaking during the rotation of the shaft 118. Reference characters similar to those of FIG. 15 indicate similar components in FIG. 16. Said valves 166 and 167 are secured to a support 172.

PROJECTION DEVICE

Referring to FIG. 17, the visible images formed on the film surface have light from a light source directed through them and the projected images are inverted with respect to the objective images due to the projection through a conventional convex lens 66. This can be corrected by providing a rectangular prism 20, mounted on a sliding rail 64, as shown in FIG. 2. The prism 20 is on a support 174 which is inserted into the sliding rail 64 in the direction of the arrow 64a and which can be fixed in a suitable position by a stop bolt 175 so that the prism 20 does not move during projection.

FILM FORWARDING MEMBERS

The rollers, sprockets and claws of the pulldown mechanism for forwarding the film touch only the side areas of the front surface and the back face of the film in a way similar to that of a conventional motion picture apparatus. Special care should be taken that no solid component touches the front surface of the film where the latent or visible images are recorded in accordance with the present invention. The only exception is that the back face touches the sound drums 40 and 67 and the wipers 57 and 60 (FIG. 3). The motion picture apparatus according to the present invention minimizes the damage to the latent and visible images caused by the mechanical friction between the film and the solid components.

It has been discovered according to this invention that when an electrically conductive material, such as a metal, contacts or closely approaches, i.e. at a distance less than 0.5 mm., the film surface which is charged with a high electrostatic voltage, the high electrostatic voltage discharges and forms undesirable electrostatic patterns in addition to the desired images, even on the image areas of the film. Such undesirable patterns are converted into visible patterns which make the resultant visible images unsatisfactory. In order to prevent such discharge patterns, it is necessary that the rollers, sprockets, claws, and aperture plate, which must contact the film prior to the formation of the visible images on the film, be made of an insulating material, such as organic plastics, glass or ceramics, having an electrical specific resistivity higher than 10^9 ohm-cm. Preferred materials are polyacetal resin, polymethyl methacrylate resin, polyethylene resin, polycarbonate resin, polytetrafluorethylene resin, epoxy resin and phenolic resin. A material having a high electric resistivity and a high resistance to mechanical wear is especially needed for the claws of the sprockets 31, 39 and 48 and the pulldown mechanism 35. Such parts are subjected to a large stress over a small area as a result of pulling on the perforations of the film. Claws made from diamond, ruby or sapphire having a hardness greater

than 7, and preferably, greater than 9 on the Mohs scale are useful. The following examples indicate preferred embodiments of a novel sprocket and a pulldown mechanism.

EXAMPLE 9

Referring to FIG. 18, the sprocket, such as sprocket 31, 39 or 48, shown in FIG. 3, comprises a main body 178, a plate 180 having claws 179 inserted therein, and a pressure plate 181. The main body 178, the plate 180 and the pressure plate 181 are made of polycetal resin which is available as Delrin resin produced by DuPont de Nemours & Co. The claws 179 are made of a single sapphire crystal. Said claws 179 are inserted into a cutout 182 (FIG. 19) having a width which is larger toward the center of the plate 180 than at the edge. This is designed to prevent the claws 179 from coming out during the rotation of the sprocket. The pressure plate 181, the plate 180 and the main body 178 are combined into one body by means of six bolts and form a sprocket which is free of the discharge troubles.

EXAMPLE 10

Referring to FIG. 20, an AC source 222 is connected to a synchronous driving motor 90, a projection lamp 183 and a motor 184 for a cooling fan. A knob 185 (FIG. 21) is connected to operate switching means 185a, the above components. Said switching means 185a is a four member ganged switch, each member of which has five switch positions. When said knob 185 and arms 185b of the switches are in the first position, the entire electrical circuit of the apparatus is switched off. Advancing the knob 185 and arms 185b to the second position causes the first switch member to switch on the cooling fan motor 184. Advancing the knob 185 and arms 185b to the third position causes the second switch means to switch on the driving motor 90 in addition to keeping the cooling fan motor 184 running. Advancing the knob 185 and arms 185b to the fourth position switches on the high voltage DC source while keeping the fan motor and drive motor running, while advancing the arms 185b to the fifth position switches on the projection lamp 183 in addition to the cooling fan motor 184 and the driving motor 90. The lamp switch is coupled with a magnetic relay switch 186 because the projection lamp 183 requires a large amount of electrical power. When the DC source 187 is switched on an electronic circuit, associated with the sound, reproduction is also switched on. The DC source supplies the necessary power to the high voltage circuit 188 for the corona discharge units 30 and 50 and to the electronic circuit of the sound recording and reproducing units. A switch 189 is mounted on the main dark space 27 and is positioned in the on or off position depending on whether the cover 9 is closed or open, respectively, in order to prevent the operator from coming into contact with the dangerous high voltage. The high voltage circuit is made compact by employing the conventional high voltage circuit for the cathode-ray tube of a conventional television set designed for home use.

The midpoint of the output of the high voltage circuit 188 is grounded to the body of the apparatus. Two output cables 73 and 87 (FIG. 5 and FIG. 10) are connected to the corona generating units 30 and 50, respectively, and have a polarity determined by the charge polarity of the developing liquid.

In the case of recording the sound directly from a conventional television set, said sound can be recorded by switching a knob 190 in FIG. 21 which closes a switch 223 in FIG. 20, adjusting the recording level adjusting means 191, connecting the output of the sound signal to an input terminal 192, amplifying the sound signal by an amplifier 193 and magnetically recording said amplified sound on said sound track 5 by means of the magnetic head 44. A meter 194 for detecting the recording level is positioned on the control panel 16 (FIG. 21). It is convenient to monitor the sounds being recorded by employing an earplug speaker which can be connected to an output terminal of the recording monitor 195. When an opera-

tor wishes to explain the projected pictures with his voice, he can use a microphone which connects to a microphone input 196. The sound signal is amplified through a preamplifier 198 and a main amplifier 199, and is reproduced at a loud speaker 220. A sound output terminal 200 is positioned in parallel with the circuit of the loud speaker and is used for monitoring the recorded sounds.

What we claim is:

1. An electrophotographic motion picture apparatus for exposing, developing and then projecting images from a substantially flexible and transparent film having laminations constituted by, in the following order from the bottom up, a transparent polymer sheet, a transparent conductive layer, a transparent adhesive layer, and an organic photoconductive insulating layer, and further a magnetic sound-track on the back face thereof, said apparatus comprising, in combination:
 - a. a film unwinding means for unwinding a roll of fresh film;
 - b. corona discharge means for continuously applying a uniform electrostatic charge to the photoconductive top surface of the film while the film is in the dark;
 - c. means for intermittently exposing said photoconductive top surface to a visible light ray image;
 - d. sound-recording means for recording sounds on said sound-track simultaneously with the exposure of said photoconductive top surface to the visible light ray image;
 - e. a second corona discharge means for continuously applying to the back face of the film an electrostatic charge having a polarity opposite to that applied to the top surface, so as to prevent developing liquid from becoming attached to said back face;
 - f. developing means for continuously applying a dispersion-type liquid developer having particles with a polarity opposite to the charge of said photoconductive top surface while it is in the dark so as to produce visible images;
 - g. means coupled to said developing means for supplying a predetermined amount of said developing liquid at a predetermined concentration for a given time period;
 - h. developer drying means for applying hot air to said film;
 - i. an image projecting means having a lamp for projecting said visible images at a rate of motion which corresponds to the aforementioned photographing rate, said image projecting means having air cooling means flowing air over such lamp and connected to said drying means for supplying the hot air thereto;
 - j. means for reproducing the sound, recorded on said track, simultaneously with reproduction of said corresponding visible images;
 - k. a winding means for winding up the film containing said visible images and said recorded sounds; and
 - l. film forwarding means comprising guiding rollers, driving sprockets, claw mechanisms with aperture plates and developing rollers guiding the film past the aforementioned means in the recited order, and drive means coupled to said film forwarding means and driving said film forwarding means.
2. An electrophotographic motion picture apparatus as claimed in claim 1, wherein said means for applying a uniform electrostatic charge includes a film guide means having a groove therein through which the film runs while being charged with the sides of the film close to the sides of the groove for preventing the developer particles from being attracted to either side of the film.
3. An electrophotographic motion picture apparatus as claimed in claim 1, wherein said guiding roller, said driving sprockets, said claw mechanism, said aperture plate, and said developing wheels are an insulating substance having an electric resistivity greater than $10^9 \Omega\text{-cm}$.
4. An electrophotographic motion picture apparatus as claimed in claim 3, wherein said driving sprockets and said claw mechanism comprise at least one claw of a hard insulating substance having an electric resistivity greater than $10^9 \Omega\text{-cm}$. and a mechanical hardness greater than 7 on the Mohs Scale.

5. An electrophotographic motion picture apparatus as claimed in claim 4, wherein said claw is of a material selected from the group consisting of diamond, ruby and sapphire.

6. An electrophotographic motion picture apparatus as claimed in claim 1, wherein said means for exposing said fresh film includes an image finder for monitoring the visible images, said image finder comprising a film pressure plate having an opening equivalent in size to a single image frame; a convex lens system into which light coming through the film is directed, means for turning the path of a light beam transversely receiving the light from said convex lens system, and means for focusing the visible images on the human eye and directed toward said means for turning a light beam.

7. An electrophotographic motion picture apparatus for exposing, developing and the projecting images comprising in combination:

1. a substantially flexible and transparent film having laminations constituted by, in the following order from the bottom up,
 - a. a transparent polymer sheet,
 - b. a transparent conductive layer,
 - c. a transparent adhesive layer,
 - d. an organic photoconductive insulating layer, and
 - e. a magnetic sound-track on the back face thereof; and
2. an apparatus for handling said film and sound-track and in combination:
 - a. a film unwinding means for unwinding a roll of fresh film;
 - b. corona discharge means for continuously applying a uniform electrostatic charge to the photoconductive top surface of the film while the film is in the dark;
 - c. means for intermittently exposing said photoconductive top surface to a visible light ray image;
 - d. sound-recording means for recording sounds on said sound-track simultaneously with the exposure of said

photoconductive top surface to the visible light ray image;

- e. a second corona discharge means for continuously applying to the back face of the film an electrostatic charge having a polarity opposite to that applied to the top surface so as to prevent developing liquid from becoming attached to said back face;
- f. developing means for continuously applying a dispersion-type liquid developer having particles with a polarity opposite to the charge of said photoconductive top surface while it is in the dark so as to produce visible images;
- g. means coupled to said developing means for supplying a predetermined amount of said developing liquid at a predetermined concentration for a given time period;
- h. developer drying means for applying hot air to said film;
- i. an image projecting means having a lamp for projecting said visible images at a rate of motion which corresponds to the aforementioned photographing rate, said image projecting means having air cooling means flowing air over such lamp and connected to said drying means for supplying the hot air thereto;
- j. means for reproducing the sound, recorded on said track, simultaneously with reproduction of said corresponding visible images;
- k. a winding means for winding up the film containing said visible images and said recorded sounds; and
- l. film forwarding means comprising guiding rollers, driving sprockets, claw mechanisms with aperture plates and developing rollers guiding the film past the aforementioned means in the recited order, and drive means coupled to said film forwarding means and driving said film forwarding means.

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