United States Patent [19]

Sato et al.

[11] **3,750,624**

[45] **Aug. 7, 1973**

[54] **APPARATUS FOR DEVELOPING ELECTROPHOTOGRAPHIC CONTINUOUS WEB MATERIAL**

[75] Inventors: **Masamichi Sato; Osamu Fukushima; Seiji Matsumoto,** all of Asaka, Japan

[73] Assignee: **Fugi Photo Film Co., Ltd.,** Minami, Ashigaka-shi Kanagawa, Japan

[22] Filed: **July 21, 1971**

[21] Appl. No.: **164,741**

[30] **Foreign Application Priority Data**

July 21, 1970 Japan 45/63763

[52] **U.S. Cl.** ..... **118/637,** 117/37 LE, 118/DIG. 23, 355/10

[51] **Int. Cl.** **G03g 13/00**

[58] **Field of Search** ..... 118/246, 258, 423, 118/424, 427, 637, DIG. 23; 117/37 LE, 93.4 A, 111 R; 355/10, 16; 95/89 R

[56] **References Cited**

UNITED STATES PATENTS

3,556,050	1/1971	Trachtenberg et al.	118/637
3,669,073	4/1969	Savit et al.	118/637
3,169,887	2/1965	York	118/637
3,577,259	5/1971	Sato et al.	117/37
3,186,326	6/1965	Schmidt	95/94
3,650,622	3/1972	Morse	355/10

Primary Examiner—Mervin Stein
Assistant Examiner—Leo Millstein
Attorney—Gerald J. Ferguson, Jr.

[57] **ABSTRACT**

An apparatus for developing electrophotographic continuous web material which comprises developing electrode drums consisting of end portions with larger diameter to hold the edge portions of an electrophotographic continuous web material and an electroconductive middle portion with smaller diameter to face the surface holding electrostatic latent image of the electrophotographic material with a small distance thereto, support drums to be brought into intimate contact with the rear surface of the material, the developing electrode drums and the support drums being alternatively in a container for liquid developer so as that the material can be wound on the drums to form approximately semi-circular contact with each of the drums, fixed developing electrodes curved and provided along the periphery of the support drums, means for driving the electrophotographic material under tension, and means for supplying liquid developer between the electrophotographic material and the fixed developing electrodes or the smaller diameter portions of developing electrode drums along the advancing direction of the electrophotographic material.

2 Claims, 6 Drawing Figures

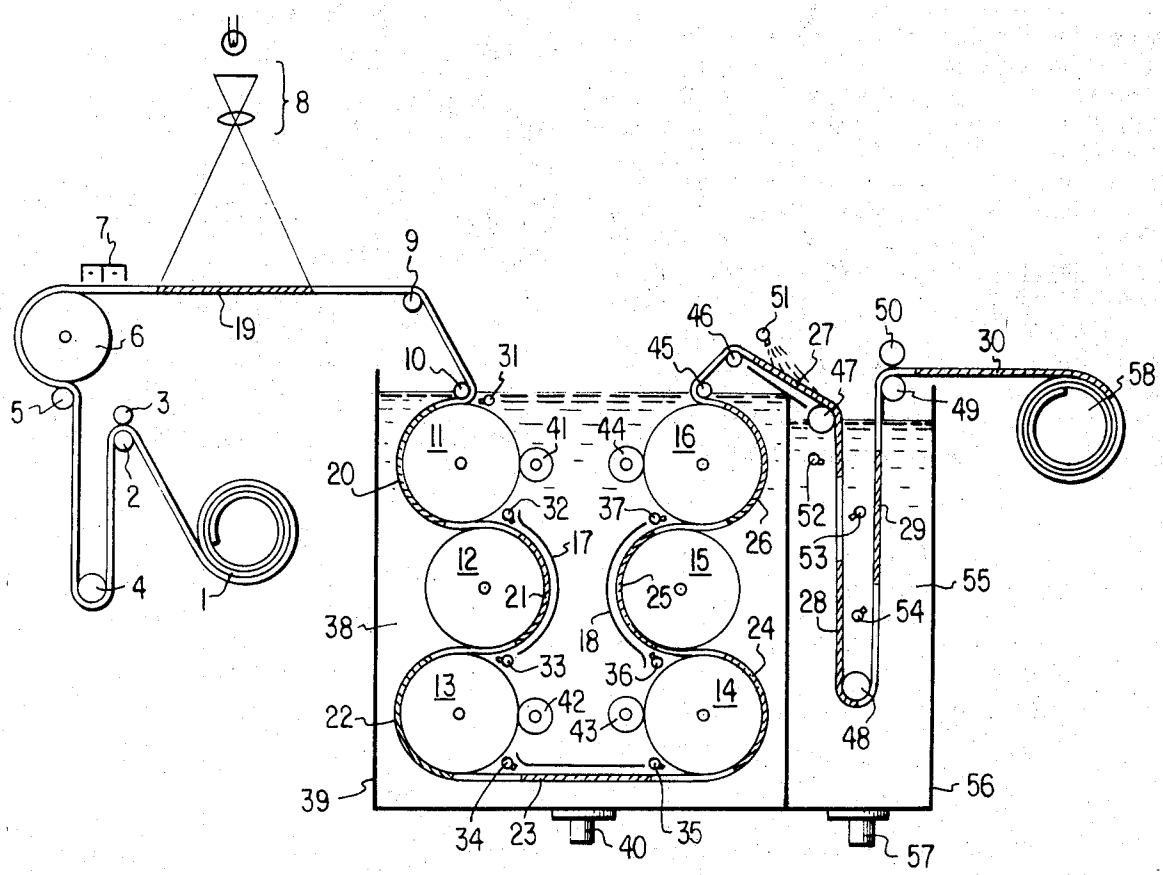
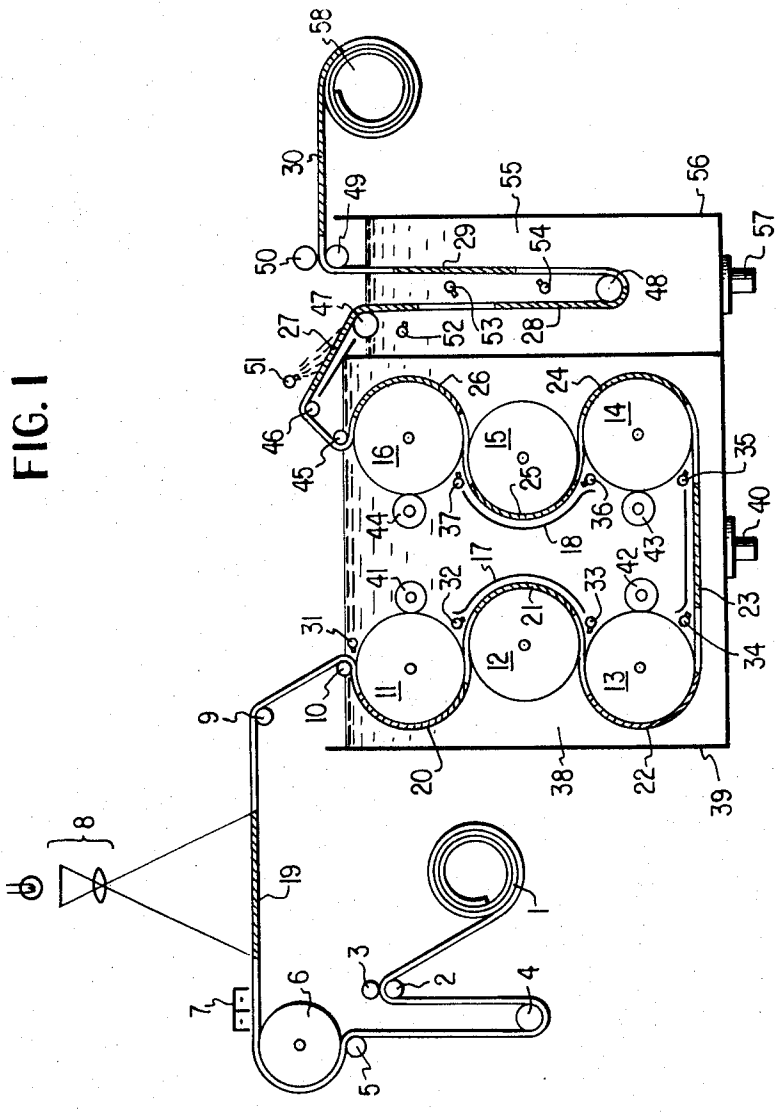


FIG. 1

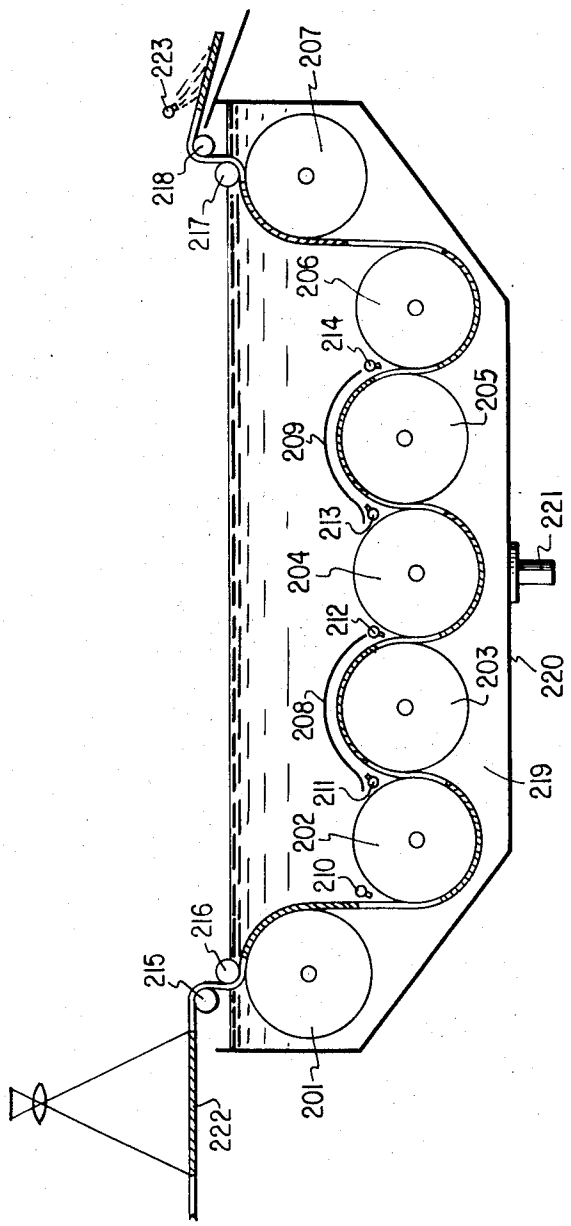


INVENTORS.
MASAMICHI SATO
OSAMU FUKUSHIMA
SEIJI MATSUMOTO

BY *Ferguson & Baker*

ATTORNEYS.

FIG. 2



INVENTORS.
MASAMICHI SATO
OSAMU FUKUSHIMA
SEIJI MATSUMOTO

BY Ferguson & Baker

ATTORNEYS.

FIG. 3

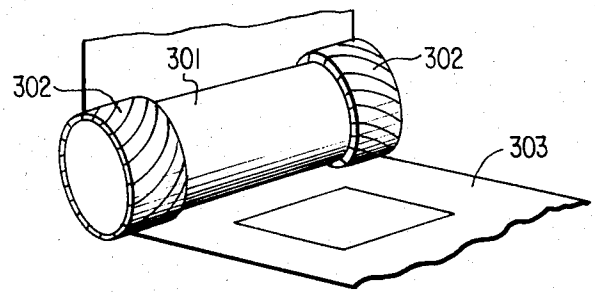
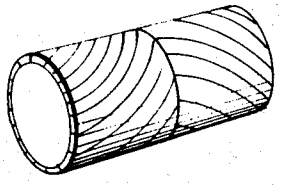


FIG. 4



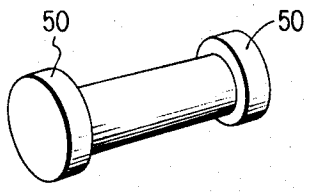


FIG. 5

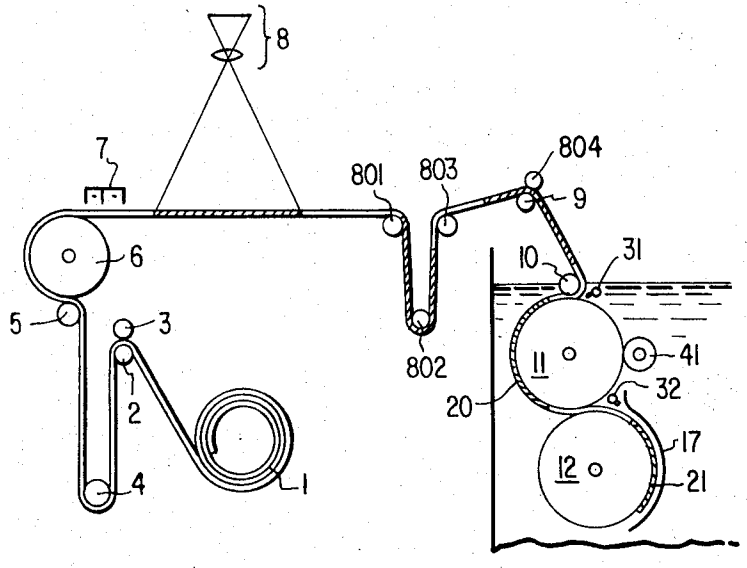


FIG. 6

INVENTORS.
MASAMICHI SATO
OSAMU FUKUSHIMA
SEIJI MATSUMOTO

BY Ferguson & Baker
ATTORNEYS.

APPARATUS FOR DEVELOPING ELECTROPHOTOGRAPHIC CONTINUOUS WEB MATERIAL

BRIEF EXPLANATION OF THE DRAWING

FIG. 1 is a cross sectional side view of electrophotographic apparatus provided with the developing apparatus according to this invention.

FIG. 2 is a cross sectional side view of another example of developing apparatus embodying this invention.

FIGS. 3 through 5 are perspective views of the examples of developing electrode drum, support drum and dancer roller to be employed in the developing apparatus according to this invention.

FIG. 6 is a side view of a mechanism in which electrophotographic material is subjected to exposure under intermittent advancement and to developing procedure under continuous advancement.

DETAILED DESCRIPTION OF THE INVENTION

This invention relates to an apparatus for liquid developing continuous web of electrophotographic photosensitive material provided with electrostatic latent image, and particularly to an apparatus capable of providing uniform development even under intermittent advancement. In addition, the apparatus of this invention is capable of (a) extending the length of the developing path without substantially enlarging the dimensions of the apparatus and (b) extending the length of the developing time to thereby effect development of continuous tone images of extremely high quality faithful to the distribution of the electrostatic charge of the latent image.

In general an electrophotographic image is obtained by electrostatically charging uniformly an electrophotographic photosensitive layer provided on a suitable electroconductive support by means for example of corona discharge to endow photosensitivity to said layer, successively subjecting said layer to imagewise exposure of light to obtain electrostatic charge distribution according to the pattern of original image (hereinafter referred to as electrostatic latent image) and bringing said layer into contact with liquid developer comprising colored charged particle (hereinafter referred to as toner) dispersed in insulating liquid thereby depositing said colored charged particle selectively onto said electrostatic latent image. However it is very difficult to obtain, at the development, an image faithful to the latent image. The developed image is apt to become uneven particularly when the images are formed at fixed intervals on an electrophotographic material of continuous web form. The present invention is to provide an apparatus capable of forming even image faithful to the latent image even in such case of forming images successively on a continuous web.

In electrophography a developing electrode is commonly employed in order to suppress edge effect (a phenomenon of insufficient development in the central portion of a wide image area which should be developed to a high uniform density) and halo phenomenon (a phenomenon observed as lower density portion in the peripheral part of low density area adjacent to high density area) which are inherent to electrophotography.

The developing electrode consists of an electroconductive plate arranged in parallel to the surface holding the latent image thereon for the purpose of increasing the number of flux of electric force and absorbing said flux thereby obtaining an electric field distributed corresponding to the distribution of electrostatic charge. It is generally accepted that the effect of developing electrode for suppressing the edge effect and halo phenomenon becomes more marked as the distance between the developing electrode and the surface holding the latent image (hereinafter referred to as the distance of developing electrode) becomes smaller. It is practically, however, difficult to maintain said distance of developing electrode at a constant value over the whole area of developing electrode, and particularly when a small distance of developing electrode is employed, local fluctuation of said distance will lead to the uneven density in the developed image.

Generally speaking the distance of developing electrode necessarily involves local fluctuation since the surface holding the latent image and the developing electrode cannot be ideally flat. Besides when a small distance of developing electrode is employed in order to suppress the edge effect and halo phenomenon and to obtain the image exactly corresponding to the distribution of electrostatic charge constituting the latent image, said unevenness is emphasized even by the slight fluctuation of said distance. In the apparatus according to this invention, each image is brought into facing relationship with at least two developing electrodes until the completion of the development, with fresh liquid developer for each developing electrode thereby to cancel eventual fluctuation formed in each development stage.

Another advantage of this invention is that the developed image is free from streak, which is comet-tail like stain caused by deposition of toner along the flow of liquid developer (on the downstream side.) Though the cause of this phenomenon is still left to be solved, it is already known that the streak for a given photosensitive material and a given liquid developer becomes stronger at the smaller distance of developing electrode (i.e. larger effect of developing electrode) and at larger relative velocity between the surface holding the latent image and the liquid developer.

An object of this invention is to realize development by alternating the developing stages with small distance of developing electrode and with no relative velocity and those with larger distance and with certain relative velocity thereby obtaining image free from such streak and uneven development and exactly corresponding to the distribution of electrostatic charge of latent image.

For this purpose, in this invention, employed are developing electrode drums and support drums freely rotatable around the axes thereof with little friction.

The position of continuous sheet of electrophotographic material is determined by passing said material around said drums alternatively. The position of surface of said electrophotographic material can be exactly defined by winding flexible continuous sheet of electrophotographic material around a drum under suitable tension without slackening in a direction perpendicular to the surface of said material. When said material is wound around the developing electrode drum, the surface holding the latent image is maintained at a constant distance from the part working as the developing electrode, whereas said surface is maintained at a constant distance from fixed developing electrodes arranged in facing relationship with said support drums when said material is wound around said

support drums. Thus, in this invention, it is possible to define the distance to the developing electrode at an exactly prescribed value.

In order to prevent mutual displacement between the drum and the continuous electrophotographic web material and further to prevent the formation of longitudinal wrinkle on said material, each drum is preferred to be rotated by the friction with the electrophotographic material therearound. It is naturally possible, however, to provide separate driving means to drive each drum at a peripheral speed identical to the advancing speed of said electrophotographic material.

As for the developing electrode drum in the apparatus according to this invention, the electrophotographic material is driven or standstilled by means of facing its latent surface to the developing electrode drums.

In this apparatus the development is realized by supplying liquid developer in the space between the surface of developing electrode drum and the surface holding the latent image of continuous sheet electrophotographic material while said material is advanced and by retaining said liquid developer within said space while said material is in standstill. When the surface holding the latent image is maintained in facing relationship with the developing electrode drum, said material is driven so as to have no relative velocity between these two elements both when said material is advanced or brought to standstill. As the result streak phenomenon does not appear even if the development is carried out with reduced distance of developing electrode. When the continuous electrophotographic web material is driven by and brought to standstill on support drum, a fixed developing electrode is provided at a certain distance from the surface holding the latent image. The advancing of electrophotographic material on the support drum will generate relative velocity between the surface holding the latent image and the developing electrode and thus will easily lead to the formation of streaks. Thus, in this case, the streak phenomenon is prevented by increasing the distance of developing electrode compared with the case of drum-shaped developing electrode. According to the basic principle the latent image can be rendered visible exactly corresponding to the distribution of electrostatic charge.

This invention will be further clarified by the following description in reference to the attached drawings. In FIG. **1** showing an example of electrophotographic apparatus provided with the developing mechanism embodying this invention, represented are an electrophotographic material **1** in roll state with the photosensitive layer thereof outward, a pair of pinch rollers **2** and **3** composed for example of rubber rollers for advancing said electrophotographic material by a determined amount, a dancer roller **4** shaped for example as shown in FIG. **5** to advance said electrophotographic material by pinching said material between the flanges **50** thereby giving a tension to said material to prevent slackening thereof, and a pinch roller **5** preferably made of elastic material such as rubber to press said electrophotographic material against a drun **6** which advances said electrophotographic material intermittently to define the position of image in longitudinal direction. Said electrophotographic material can be driven for example by means of combination of sprocket provided at the extremities of said drum **6** and perforations provided at the edge portions of said electrophotographic material. Such combination provides registration not only in the longitudinal but also transversal direction, and is particularly suitable for obtained well registered image in case of multi-color reproduction. For registration also available are other known methods such as by advancing the photosensitive material by determined amount by optical mark recognition in longitudinal direction and displacement of optical system in transversal direction. This mechanism is also provided with a corona discharge device **7** for effecting corona discharge on the surface of photosensitive layer while said electrophotographic material is advanced to endow an even surface charge on said surface, an optical system **8** to project the original image on said photosensitive layer thereby modulating the surface charge on said photosensitve layer corresponding to the original image to form latent image, and guide rollers **9** and **10** made for example of rubber for guiding the electrophotographic material after exposure toward the developing mechanism.

Besides the electrophotographic material can be effectively moistened, prior to the contact with liquid developer, with highly insulating liquid in order to prevent the penetration of liquid developer into said material, and such moistening operation can be conveniently carried out between the rollers **9** and **10**.

Then the continuous electrophotographic web material is guided to the developing section embodying this invention.

In this section provided are developing electrode drums **11**, **13**, **14** and **16**, and support drums **12** and **15**. The electrophotographic material is wound around the developing electrode drums with the latent image surface thereof inward, while wound around the support drums with said surface outward. The support drums are provided with developing electrodes **17** and **18** shaped as shown in FIG. **3**.

The developing electrode drum consists, as shown in FIG. **3**, of end portions **302** with larger diameter and middle portion **301** with smaller diameter. Said end portions **302** with larger diameter support the edge portions of electrophotographic material, while said middle portion **301** with smaller diameter faces the latent surface of said material with a small distance to work as the developing electrode.

Thus, the distance of developing electrode is determined by the difference of diameter of the portion and middle portion. The portions with larger diameter **302** are provided with spiral recesses of opposite directions in order to prevent slackening of electrophotographic material in the transversal direction thereof which might lead to uneven distance of developing electrode.

The support drums can be made of flat cylinder, but is preferably provided with spiral ditches of opposite directions from the center to the ends thereof. Naturally said ditches should not be large enough to cause deformation of electrophotographic material which leads to the formation of ditch pattern on the developed image due to uneven developing. Since the fixed developing electrode is mounted outside the support drum and since a distance exists between the fixed developing electrode and the latent image surface on the electrophotographic material wound around the support drum, the fixed developing electrode plus the support drum are larger than the developing electrode drums. The electrophotographic material advanced in-

termittently is brought to standstill on each support drum and developing electrode drum when said material reaches exact facing relationship with the developing electrode. In FIG. 1, the image areas on the electrophotographic material are shown by the hatched portions 19–30. The nozzles 31–37 for liquid developer supply liquid developer between the developing electrodes and electrophotographic material exclusively when said material is advanced, but such supplying operation is interrupted while said material is stopped. The developing section containing developing electrode drums, support drums and supply nozzles is mounted in a container 39 filled with liquid developer. Said liquid developer is removed from an outlet 40 provided at the bottom of said container and cycled to the nozzle through a pump (not represented).

When the electrophotographic material is wound around a developing electrode drum, the liquid developer is retained between the electrode surface of developing electrode drum and the latent image surface of said material without relative velocity thereto thereby enabling to realize development exactly corresponding to the charge distribution of latent image even with small distance of developing electrode. On the contrary when the electrophotographic material is wound around a support drum, the latent image surface will have a relative velocity with respect to the developing electrode and therefore to the liquid developer when said material is advanced since the developing electrode is fixed in this case. Consequently, in this case, it is necessary to employ a larger distance of developing electrode in order to prevent streak phenomenon. For cleaning the electrode surface of developing electrode drums provided are cleaners 41–44. These cleaners are provided because particularly small distance of developing electrode on developing electrode drums is apt to induce deposition of reversed toner image of latent image on said drums. Said cleaner can be effectively composed of soft material such as sponge or felt pressed against the surface of developing electrode, or of a rubber roller pressed against said electrode as shown in FIG. 1. Furthermore, a fixed developing electrode is provided between the developing electrode rollers 13 and 14 so as to face the latent image surface of electrophotographic material. The distance of said developing electrode, however, should be made considerably large as the distance between the latent image surface of electrophotographic material and the developing electrode cannot be defined exactly. Further, this developing electrode can be dispensed with in certain cases.

In an apparatus as shown in FIG. 1, satisfactory results could be obtained by employing the distances of developing electrodes of 0.5, 2, 0.3, 2, 0.2, 2 and 0.1 mm in this order. As to the material composing these components, the support drum and the larger diameter portions 302 of the developing electrode drums are preferred to be made of metal, plastics or rubber while the smaller diameter portions of said developing electrode drums are preferred to be made of electroconductive material such as metal.

In this section further provided are guide rollers 45–47 for guiding the electrophotographic material after the development toward the rinse section. Said rollers can be made of metal, rubber, plastic, etc., and are preferably provided with flat surface or with spiral ditches similar to those on the developing electrode drums shown in FIG. 4. A dancer roller 48 continuously takes up the electrophotographic material advanced intermittently in the exposure and developing sections and gives a constant tension to said material at the winding on the roller 58. The shape of said dancer roller is shown in FIG. 5. Thus, the tension applied to said material in the exposure and developing sections is kept constant by means of dancer rollers 4 and 48. Although these dancer rollers become unnecessary if the intermittent winding and unwinding of said electrophotographic material are completely synchronized, said rollers are extremely useful for absorbing aberration in the advancing. In the rinse section provided are washing solution 55, a washing solution container 56, washing solution nozzles 51–54 and an outlet 57 provided at the bottom of the washing solution container, from which the washing solution is cycled to said nozzles through a pump (not represented). The electrophotographic material washed with the washing solution 55 is driven by a pair of pinch rollers 49 and 50, and taken up on a roller 58. Said rollers 50 and 49 are preferably made of smooth metal roller and rubber roller, respectively. In case of driving either one of said rollers 49 and 50, the take-up roller 58 is preferably driven by means of a constant-tension motor. In this example, in case of forming images at a fixed interval on a continuous web of electrophotographic material, said material is advanced intermittently in the exposure and developing sections, and when said material is brought to sandstill in the liquid developer each image area is kept in a fixed position by means of a support drum or a developing electrode drum to face a developing electrode with a prescribed distance thereto in order to prevent any unevenness during the developing or processing. Winding around a cylindrical surface facilitates to obtain uniform distance of developing electrode and thus to prevent uneven development even in a single developing stage, and this facility is further multiplied by employing plural developing stages in case of the example shown in FIG. 1. Furthermore supply of fresh liquid developer between the electrophotographic material and developing electrode between the succeeding developing stages is also effective in suppressing the uneven developing and insufficient development.

Although the example shown in FIG. 1 is provided with six support drums, it is naturally also possible to extend the length of developing section by providing a larger number of support drums vertically or by providing additional drums horizontally after the drum 16 instead of directly connecting to the rinse section.

This developing apparatus is also capable of effecting so-called reversal development by means of toner particles charged in the same sign as the electrostatic charge composing the electrostatic latent image. For this purpose the developing electrodes are supplied with suitable electric potential while the support material of the electrophotographic material is grounded. Also it is possible to decrease the potential applied in correspondence with the attenuation of the charge composing the electrostatic latent image by applying different potentials to the developing electrodes.

FIG. 2 shows another example of this invention, in which drums are arranged horizontally in a line. In this example provided are support drums 201, 203, 205 and 207 and developing electrode drums 202, 204 and 206 which are similar to those employed in the apparatus of FIG. 1, fixed developing electrodes 208 and 209 which

may also be provided for the support drums **201** and **207**, and nozzles **210-214** for liquid developer. The liquid developer **219** is contained in a container **220**, and is supplied from an outlet provided at the bottom thereof to said nozzles **210–214** through a pump (not represented).

The continuous sheets of electrophotographic material is provided with image areas as shown by black portions, and the dimentional relationship of the components of the developing section is determined so as that all the image areas are brought into facing relationship with developing electrodes when said material is brought to standstill in the developing section. The supply of liquid developer is realized only when the same material is advanced. This section is also provided with guide rollers **215–218** similar to those employed in the apparatus shown in FIG. **1**, and a washing solution nozzle, of which performance and effect are omitted here as they are quite similar to those in case of the apparatus shown in FIG. **1**.

Though intermittent advancement is employed throughout the developing sections in the examples thus far explained, a simple modification enables to employ intermittent exposure steps combined with continuous advancement in the developing section. An example of such apparatus is shown as a cross-sectional side view in FIG. **6**, in which the electrophotographic material forms, different from the case of FIG. **1**, a loop on the way to the roller **9** post-exposure. The guide rollers **801** and **803** can be similar to the roller **9**. A dancer roller **802** similarly shaped as the roller **4** in FIG. **1** provides a loop for converting intermittent movement into continuous movement. In this case it is necessary to drive the electrophotographic material continuously by means for example of providing a pinch roller **804** pressed against the roller **9**. In case a fixed roller is employed instead of the dancer roller **48** in FIG. **1**, the driving of the material is realized by means of a pair of pinch rollers **49** and **50** without providing the pinch roller **804**. In case of continuous advancement in the developing section, the positions of components can be determined irrespective of the location of image areas. Stated differently, it is not necessary, in this case, that the image areas shown by the hatched portions are simultaneously brought into facing relationship with the developing electrodes, as is obvious from the continuous advancement of the electrophotographic material. Though the loop of the electrophotographic material in FIG. **6** is made in air, it is also possible to make this loop in the liquid developer.

The present invention thus far explained in connection with the foregoing examples can be summarized as follows:

1. In case of developing a continuous web of electrophotographic material holding electrostatic latent image thereon, the surface holding said latent image is made to face to at least two developing electrodes.

2. Fresh liquid developer is supplied each time when the latent image is brought into facing relationship with new developing electrode.

3. The continuous web is supported around developing electrode drums and support drums provided alternatively. The support drums are provided respectively with fixed developing electrode curved coaxially thereto and mounted with a relatively large distance thereto.

4. In case of developing electrophotographic material with intermittent advancement, image areas thereon face, during the standstill period, developing electrodes respectively.

Furthermore the electrophotographic material in the foregoing explanation is not necessarily photosensitive, but can generally be a continuous flexible web holding electrostatic latent image thereon.

This invention is characterized by following four features:

1. Latent image surface is facing two or more pieces of developing electrodes at least, when developing long web having electrostatic latent image.

2. Supplying new developing liquid whenever latent image is opposed to new electrode.

3. Winding web round developing electrode or supporting drum mutually.

Deposited fixed developing electrode of arched concentric circle to supporting drum at comparative large intervals.

4. Each of images is facing to developing electrode at motionless time in case of intermittent driving when developing electrophotographic material.

Electrophotographic material is not always necessary to have sensitization, and flexible long belt bearing electrostatic latent image.

What is claimed is:

1. An apparatus for developing an electrophotographic, continuous web material which comprises (1) developing electrode drums comprising (a) end portions with a first diameter to hold the edge portions of said electrophotographic continuous web material and (b) an electroconductive middle portion with a diameter smaller than said first diameter facing the surface holding the electrostatic latent image of said electrophotographic material with a small distance therebetween, (2) support drums in substantially direct contact with the rear surface of said electrophotographic material, said developing electrode drums and said support drums being alternatingly disposed in a container for liquid developer so that said material is wound on said drums to make approximately semi-circular contact with each of said drums, (3) curved, fixed developing electrodes disposed along the periphery of said support drums, (4) means for driving said electrophotographic material under tension, and (5) means for supplying liquid developer between said electrophotographic material and at least one of said fixed developing electrodes and said smaller diameter portion of said developing electrode drums along the advancing direction of said electrophotographic material.

2. An apparatus as in claim **1** where said means for supplying liquid developer supplies the liquid developer between said electrophotographic material and both said fixed developing electrodes and said smaller diameter portions of said developing electrode drums.

* * * * *