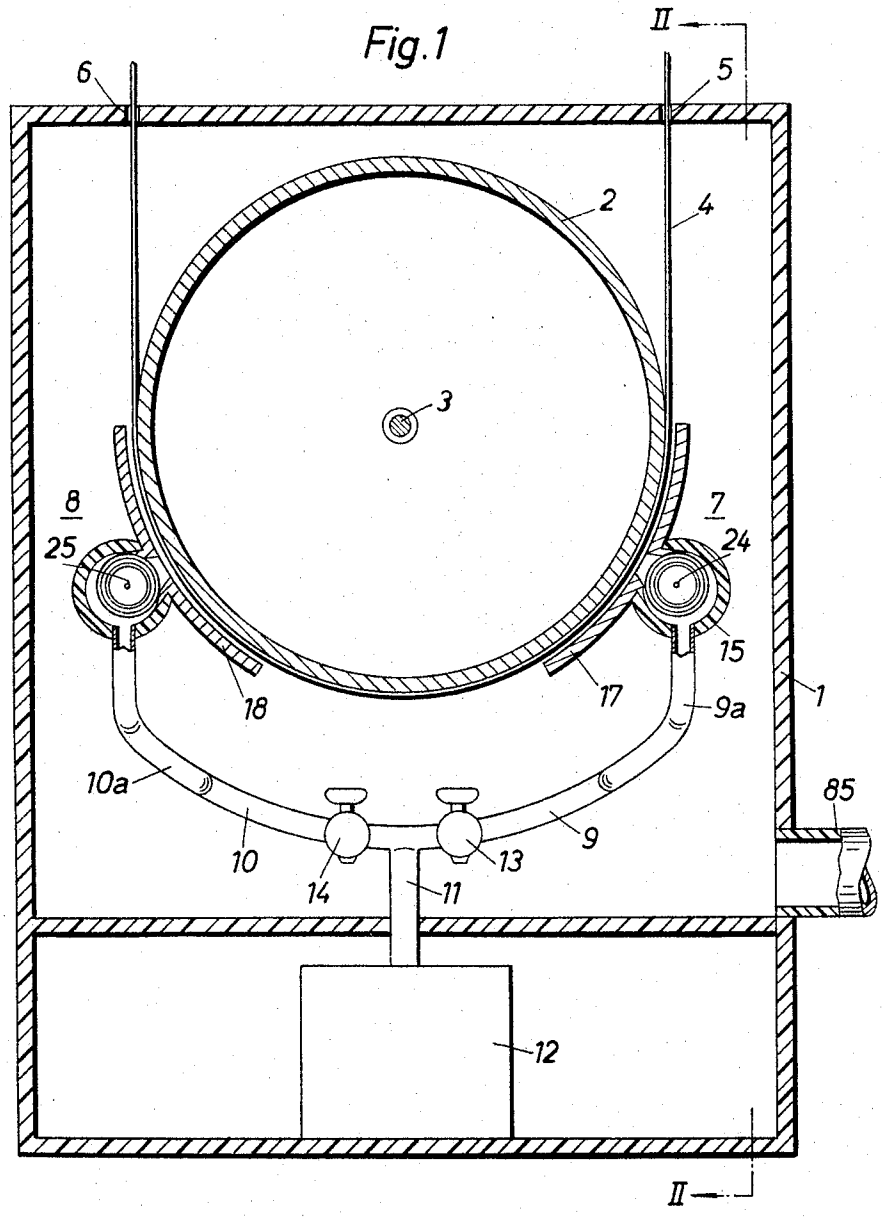
Aug. 2, 1966 G. HEYL ET AL 3,263,649

APPARATUS FOR DEVELOPING ELECTROSTATIC IMAGES

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Fig. 1

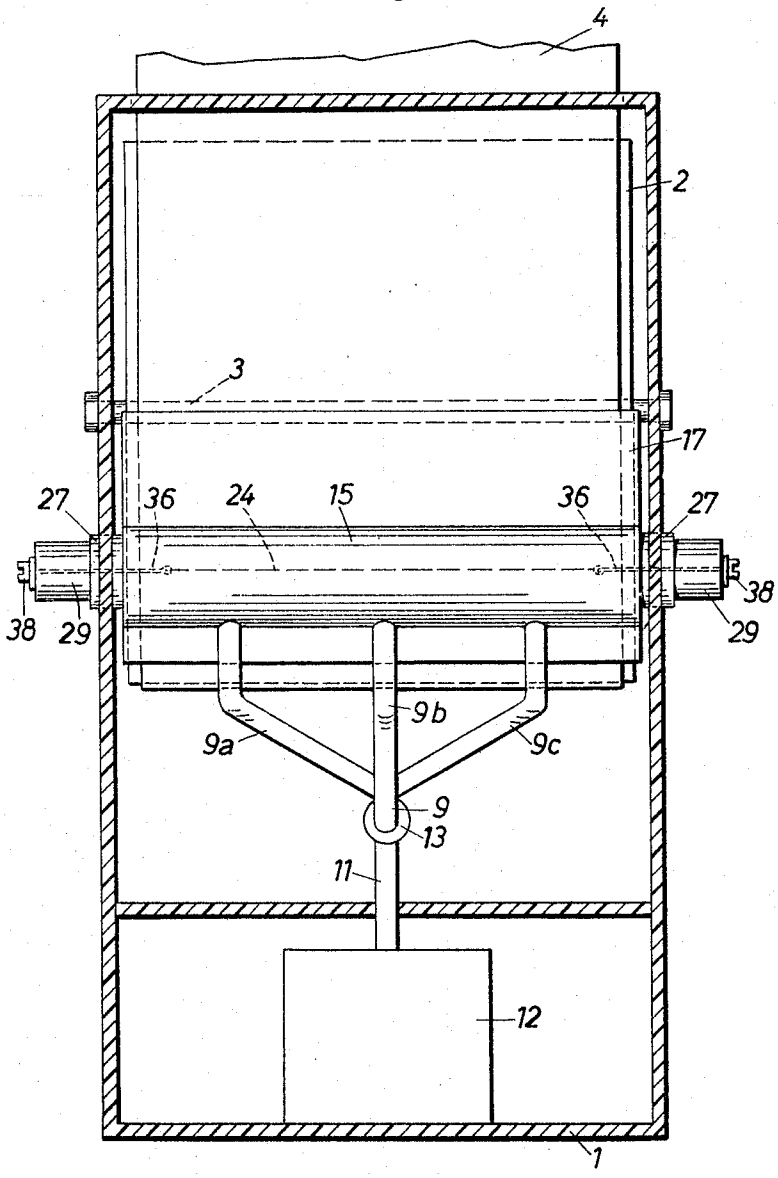


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Fig.2



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Fig.3

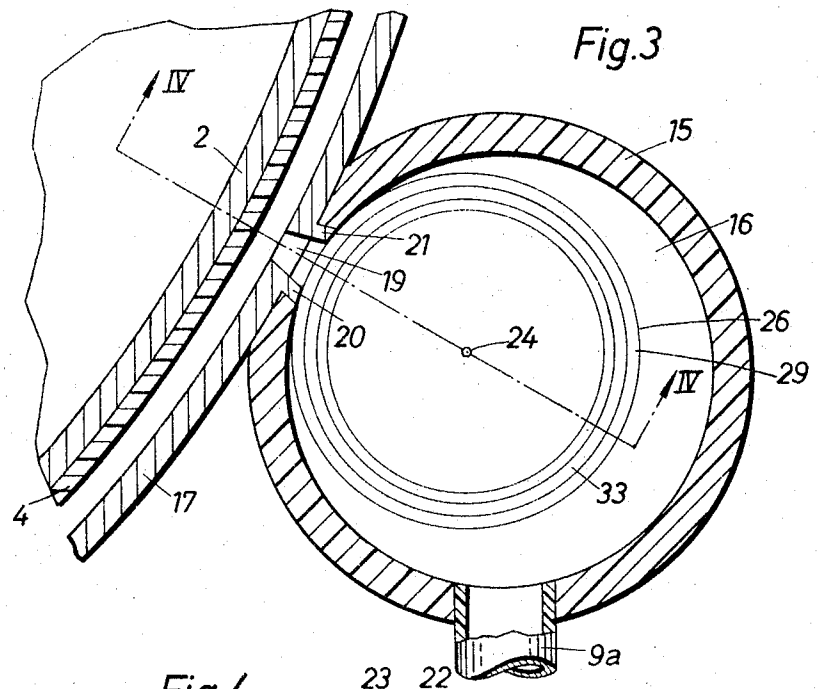
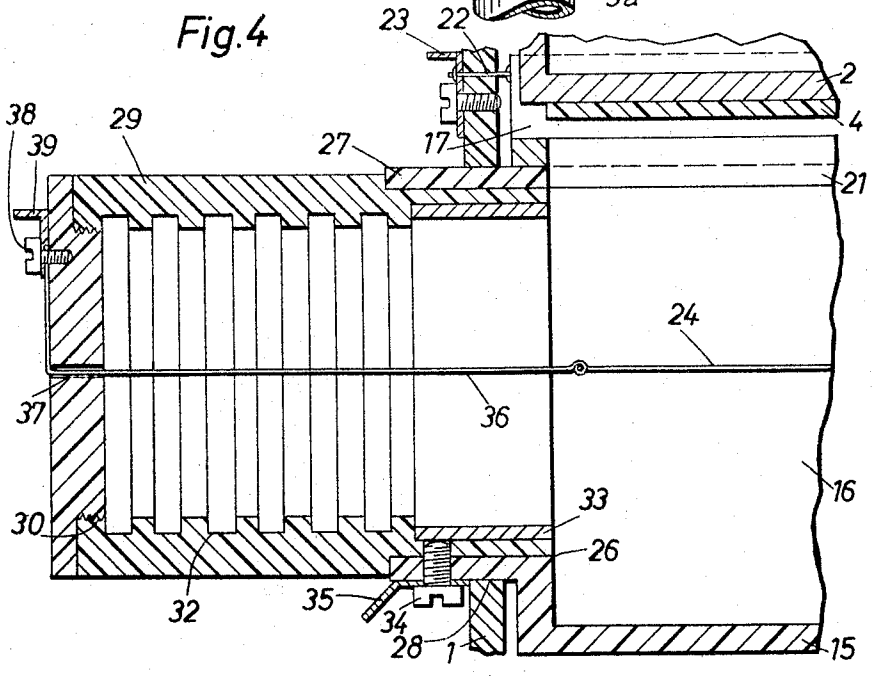


Fig.4

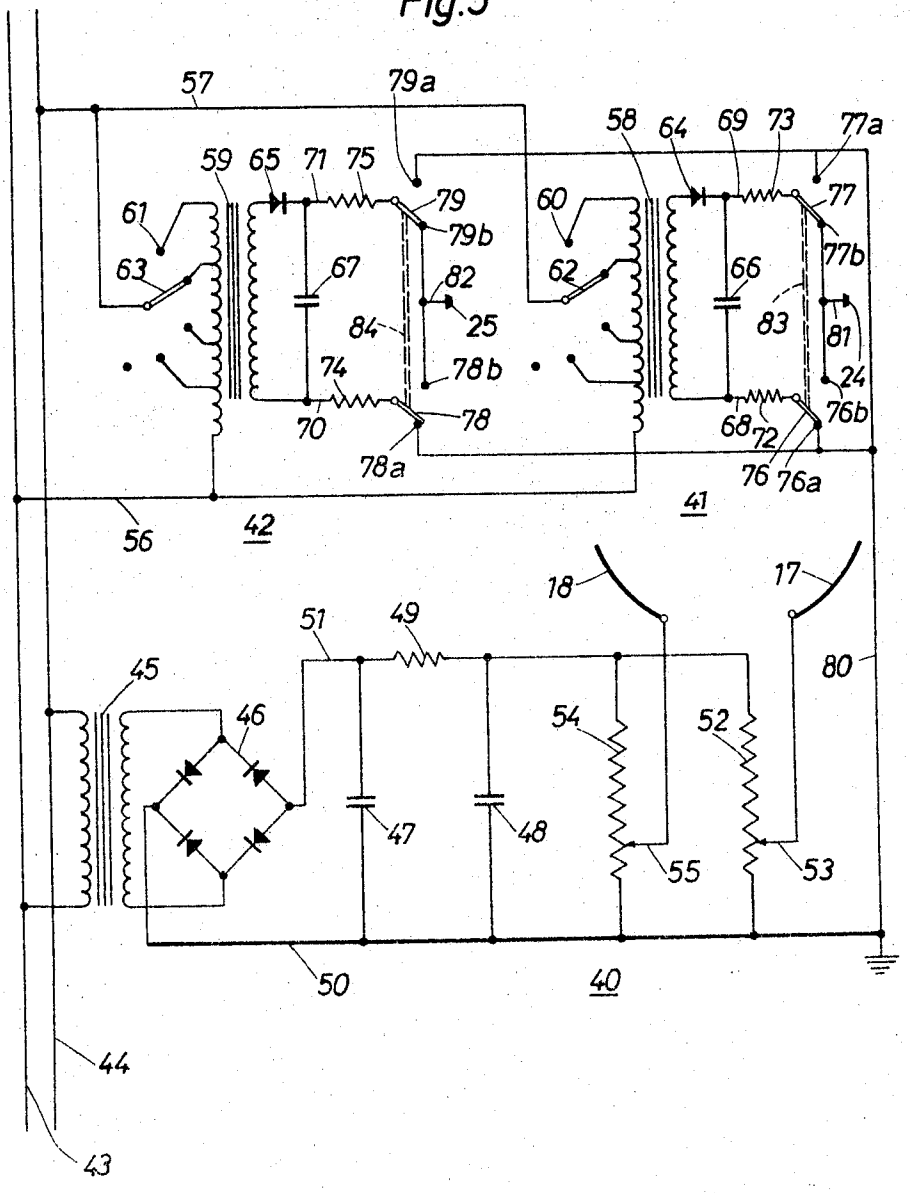


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Fig.5



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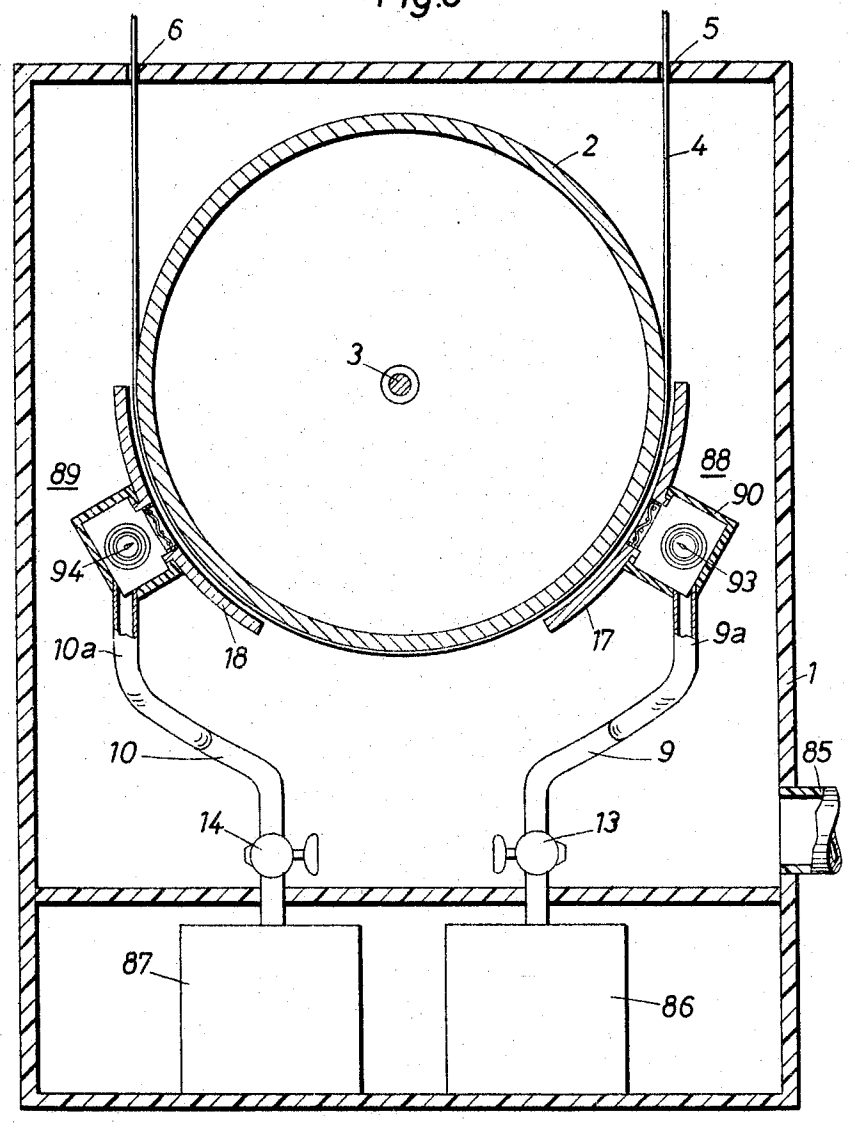
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Fig.6



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Fig.7

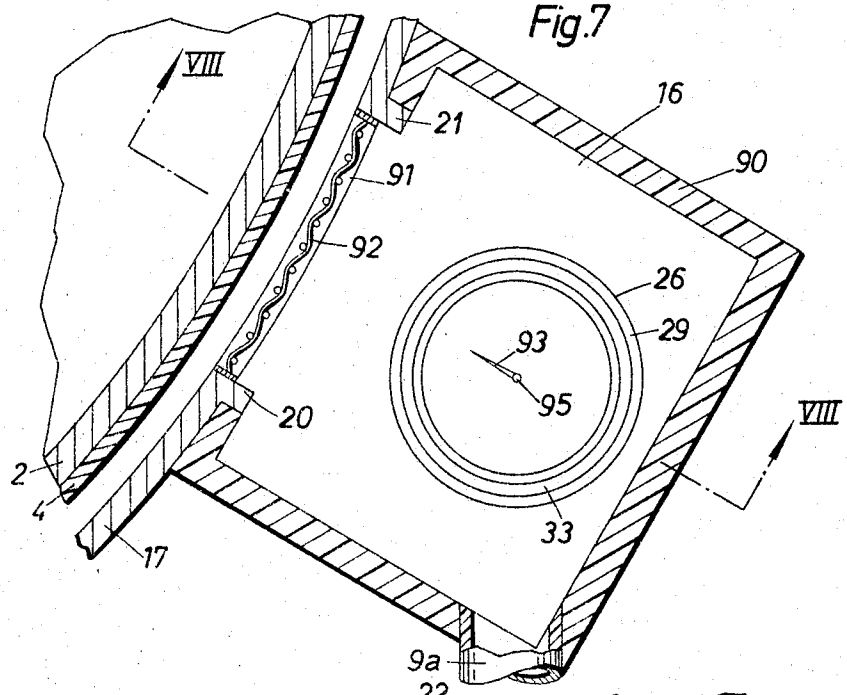
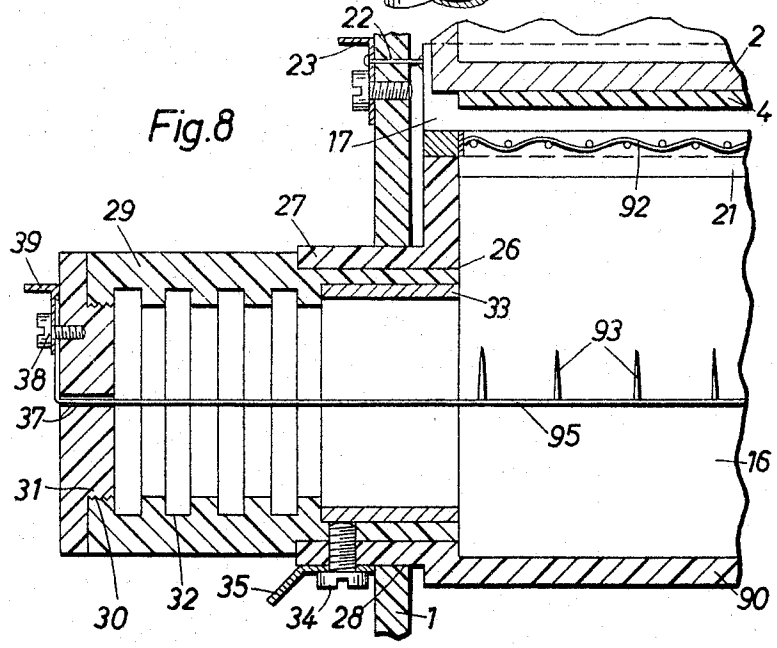


Fig.8



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3,263,649

APPARATUS FOR DEVELOPING ELECTROSTATIC IMAGES

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Filed Apr. 19, 1963, Ser. No. 274,357
Claims priority, application Germany, Apr. 19, 1962, A 40,008, A 40,009
16 Claims. (Cl. 118—637)

The present invention relates to electrophotography.

In particular, the present invention relates to apparatus for developing electrostatic images such as electrostatic images which are formed in photoconductive material, as is well known in the art of electrophotography.

Although structures for developing electrostatic images have been known for some time, these known structures suffer from various drawbacks. Thus, it is well known that the development of electrostatic images can be brought about by directing to the material which is formed with the images particles of an aerosol developer, these particles being electrostatically charged so as to deposit on the material provided with the electrostatic images and thus render the images visible, the charged particles having a color which renders them visible when deposited on the material which is formed with the electrostatic image. However, the charging of such developer particles takes place at a relatively great distance from the material which is formed with the electrostatic images and the charged particles are conducted through relatively small passages to the material such as a photoconductive material formed with the electrostatic images with a result that there is a substantial, undesirable loss of developer and in addition the relatively small passages, which is to say small in cross section, do not infrequently become clogged. Furthermore, in order to operate a developing apparatus of the above type economically it is necessary to move the images through the developing apparatus at a relatively fast rate, and conventional apparatus very often is incapable of developing images satisfactorily at a fast enough rate to render the operations profitable. Furthermore, it is often desired to carry out treatments of various types, in addition to development, and such treatments are inconvenient to carry out in conventional apparatus.

It is accordingly a primary object of the present invention to provide a developing apparatus or a treating apparatus which will avoid the above drawbacks.

Thus, one of the objects of the present invention is to provide a structure which will prevent any undesirable loss of developer and which will avoid the possibility of clogged passages through which the developer moves.

Another object of the present invention is to provide an apparatus capable of very quickly treating electrostatic images in a fully satisfactory manner so that the output of the apparatus is sufficiently great to render it economically profitable.

It is furthermore an object of the present invention to provide an apparatus of the above type which is flexible enough to permit different types of treatments to be carried out in a convenient, inexpensive manner.

It is also an object of the present invention to provide extremely simple structure which is very reliable in operation and which can provide a relatively high output with completely satisfactory operation after a long period of use.

It is furthermore an object of the present invention to provide a structure of the above type which can be regulated in such a way that the best possible development of the electrostatic images is guaranteed.

The objects of the present invention also include an apparatus which will require the charged developer particles to move through only an extremely short distance so that the loss of developer will be extremely small.

Furthermore, it is an object of the present invention to provide a structure which, while maintaining the distance through which the charged particles travel extremely small, nevertheless effectively shields the developing area from the high voltage of the structure which charges the developer particles.

The objects of the present invention also include the provision of an apparatus which can develop electrostatic images on a continuously moving band while guaranteeing completely satisfactory development of the images even though the band continuously travels at a relatively high rate of speed.

With these objects in view the invention includes, in an apparatus for developing electrostatic images, a developing electrode located adjacent the material which is formed with the images and formed with an opening through which particles of an aerosol developer pass to the material formed with the images. A charging chamber forms a unit with the developing electrode and is formed with an opening aligned with the opening of the developing electrode so that particles of the aerosol developer may pass from the interior of the charging chamber through the openings to the material which is formed with the electrostatic images. A charging means is located within the charging chamber in alignment with the openings and adjacent to the developing electrode for charging the particles of the developer as they advance toward these openings, and the distance between the charging means and the developing electrode is great enough to prevent arcing therebetween. The above structure forms an assembly of a treating unit, and a pair of such treating units are provided according to the invention adjacent to the material which is to be treated so that it becomes possible to provide a pair of treatments, and suitable conduits communicate with the treating units to supply the latter with treating materials such as an aerosol developer.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which:

FIG. 1 is a partly schematic sectional elevation of one possible embodiment of a developing apparatus according to the present invention;

FIG. 2 is a sectional elevation of the structure of FIG. 1 taken along line II—II of FIG. 1 in the direction of the arrows;

FIG. 3 shows on an enlarged scale part of the structure of FIG. 1;

FIG. 4 is a sectional view of the structure of FIG. 3 taken along line IV—IV of FIG. 3 in the direction of the arrows;

FIG. 5 is a wiring diagram of the structure of FIGS. 1–4;

FIG. 6 is a sectional elevation of another embodiment of a developing structure according to the present invention;

FIG. 7 shows on an enlarged scale part of the structure of FIG. 6; and

FIG. 8 is a sectional view of the structure of FIG. 7 taken along line VIII—VIII of FIG. 7 in the direction of the arrows.

Devices for providing electrophotographic pictures include structures for charging a material such as a suitable photoconductive material so that it will be provided with an electrostatic charge which upon exposure to a

given image will become electrostatically charged according to the configuration of the image so that in this way the photoconductive material or the like is formed with a latent electrostatic image. Structures for charging the photoconductive material or the like and for providing the latent electrostatic image therein through suitable exposure of the charged photoconductive material are well known and do not form part of the present invention so that such structures are not illustrated. After such a latent electrostatic image is formed, it is necessary to develop the image so that it will become visible, and the structure of the present invention relates to the development of such images. As is well known such images are rendered visible by depositing on the photoconductive material suitably charged and suitably colored particles which will become deposited on the photoconductive material in accordance with the configuration of the electrostatic image so as to render the latter visible. As is well known, the charged photoconductive material, this material being in the original instance uniformly charged, is exposed to light reflected from or passing through the photograph, printed sheet, or the like which is to be reproduced, and as a result those portions of the charged photoconductive material which receive the light lose their charge to an extent determined by the intensity of the light while those portions of the charged photoconductive material which do not receive any light retain their electrostatic charge, and as a result, after exposure, the intensity and distribution of electrostatic charge in the photoconductive material corresponds to the image projected onto the photoconductive material and thus forms an electrostatic latent image. The photoconductive material may take the form of a photoconductive layer carried by a suitable support such as a band of paper, for example. The photoconductive layer can be made up, for example, of zinc oxide in a suitable binder medium.

Referring to FIG. 1, it will be seen that the developing apparatus of the invention includes a housing **1** in which the developing structure is located, and the developing structure located in the housing **1** is capable of being removed therefrom and interchanged with other apparatus. Within the housing **1** is located a rotary drum **2** made of a conductive material, the drum **2** being supported for rotation on a stationary shaft **3** which is carried by the housing **1**, and the drum **2** serves to guide through the housing **1** the paper band **4** or the like which carries the layer of photoconductive material. The band **4**, after passing through suitable charging and exposing devices, passes through the opening **5** in the top wall of the housing **1** downwardly into the latter, around the drum **2**, and then through a discharge opening **6** out of the housing **1** to an unillustrated take-up spool, for example, or to a cutting device, or, if desired, to a device for transferring the developed images from the band **4** to suitable copy sheets or the like on which reproductions are made. The band **4** is continuously transported by an unillustrated driving device which includes an electric motor, and during its movement through the developing apparatus of FIG. 1 the drum **2** rotates in a clockwise direction, as viewed in FIG. 1, the exterior surface of the drum of course being frictionally engaged by the surface of the band **4** opposite to that which carries the photoconductive material.

Adjacent to the band **4**, within the housing **1**, there are arranged a pair of treating units **7** and **8** respectively located on opposite sides of a vertical plane which passes through the shaft **3**, and it will be noted that these treating units **7** and **8** are located adjacent the drum **2** and define with the latter gaps through which the band **4** passes. A pair of conduits **9** and **10** respectively communicate with the treating units **7** and **8** for supplying the latter with treating materials such as aerosol developer. The conduits **9** and **10** communicate with a common conduit **11** which communicates in turn with a developer supply apparatus **12**, so that in the illustrated example the supply apparatus **12** is common to both of the treating units **7** and **8** and is capable of supplying both units with aerosol developer. The pair of conduits **9** and **10** respectively carry valves **13** and **14** which can be adjusted independently of each other and which when closed cut off the flow of developer toward the treating units. These valves can be adjusted so as to regulate the stream of aerosol developer which is delivered to each treating unit **7** and **8**. Each of the conduits **9** and **10** is provided with a plurality of branches distributed along and communicating with the treating unit to which it is connected. Thus, FIG. 2 shows the branches **9***a*, **9***b*, **9***c* of the conduit **9** which branch from the latter and communicate with the treating units **7** at spaced portions thereof. The conduit **10** is constructed in the same way, and only the branch **10***a* thereof is visible in FIG. 1. These branches of the conduits serve to distribute the developer with sufficient uniformity across the entire width of the band **4**. In accordance with the particular width of the band **4** there can be more or less than the three branches shown in the particular example illustrated in the drawings.

In the particular construction shown in the drawings the developer is in the form of an aerosol obtained by atomizing a suitably colored solution. Thus, compressed air is used to break up a suitably colored solution, forcing the latter through a suitable nozzle so that the colored solution is converted into fine liquid particles which are suspended in air. The nozzle which is required to provide this aerosol developer forms part of the unit **12** and is not illustrated in the drawing. Instead of an aerosol developer composed of liquid particles it is also possible to provide a developer composed of very fine solid particles by placing in contact with a stream of air a suitable powder which becomes suspended in the stream of air, and then this stream of air or other gas is directed through the conduit **11** and then, according to the position of the valves **13** and **14** through the conduits **9** and **10** to the treating units **7** and **8**, respectively.

Both of the treating units **7** and **8** are of the same construction, and the details of the treating unit **7** are illustrated in a side view in FIG. 2 and in transverse and longitudinal sections in FIGS. 3 and 4, respectively. The treating unit **7** includes a wall means **15** which forms a chamber **16**, and this chamber is a charging chamber, as will be apparent from the description which follows. In the example illustrated the wall means **15** has the configuration of a cylinder and is made out of an electrically non-conductive material such as a suitable plastic. The branches **9***a*–**9***c* of the canduit **9** communicate with the charging chamber **16** at the lowest elevation thereof. The structure also includes a developing electrode **17** which is located adjacent the drum **2** so as to be located relatively close to the photoconductive material carried by the band **4**, and the curvature of the developing electrode **17** conforms to that of the cylinder **2** so that between the exterior surface of the drum **2** and the concave surface of the electrode **17** which is directed toward the drum **2** there is defined a gap of uniform thickness which in the particular example has a thickness on the order of 1–5 mm.

The charging chamber **16**, in which the developer particles are charged in the manner described below, and the developing electrode **17** are fixed with each other. For example, the cylinder **15** and the electrode **17** may be screwed together. The developing electrode **17** is formed with an opening through which the aerosol developer passes to the photoconductive material, and in the illustrated example this opening takes the form of an elongated relatively narrow slot **19** which extends longitudinally along the electrode **17** substantially midway between the upper and lower edges thereof, and at the upper and lower edges of the elongated, narrow opening **19** the electrode **17** is provided with a pair of flanges **21**

and 20 which extend away from the drum 2, and it will furthermore be noted from FIG. 3 in particular that the cross section of the opening 19 converges from the charging chamber 16 toward the surface of the electrode 17 which is directed toward the drum 2. The elongated strips or flanges 20 and 21 are made of electrically conductive material and they extend into an opening of the cylindrical wall 15 which is aligned with the opening 19. It will be noted that the opening of the cylinder 15 which is aligned with the opening 19 is larger than the opening 19. The flanges or strips 20 and 21 are not absolutely essential and can be omitted, if desired. As may be seen from FIG. 4, an electrically conductive lead 22 is connected to the electrode 17 for placing the latter in an electrical circuit which is described below, and the conductor 22 extends from the electrode 17 through the wall of the housing 1 to a soldering lug 23 to which the conductor 22 is also connected, and through the lug 23 the electrode 17 is placed in the electrical circuit which is described below.

In order to charge the aerosol particles which are in the charging chamber 16, a charging means is located within the chamber 16, and this charging means is aligned with the opening 19, is located adjacent to the developing electrode 17, and at the same time is spaced from the electrode 17 by a distance which is sufficiently great to prevent arcing between the charging means and the developing electrode 17. In the illustrated example the charging means is formed by an elongated wire 24 which forms a charging electrode, and this wire 24 forms a discharge wire for charging the particles of the aerosol developer as they advance through the interior of the charging chamber 16 toward the opening 19 to pass through the latter to the photoconductive material. It is to be noted that the charging chamber 16 together with the narrow elongated opening 19 and the charging electrode 24 as well as the developing electrode 17 all extend perpendicularly to the plane of FIGS. 1 and 3 in a horizontal direction and the length of these components, as is apparent from FIG. 2, corresponds approximately to the axial length of the drum 2 and to the width of the paper strip or band 4 which carries the photoconductive material, as described above.

The support means for supporting the charging electrode 24 is located at the ends thereof, and the structure of this support means at one of the ends of the charging electrode 24 is illustrated in detail in FIG. 4, the structure at the other end of the electrode 24 being the same as that shown in FIG. 4.

As is particularly apparent from FIG. 4 the charging chamber 16, which is formed by the cylinder 15, carries at its ends a pair of tubular extensions 29 which communicate with the interior of the chamber 16, and one of these tubular extensions 29 is shown in FIG. 4. The end walls of the cylinder 15 are formed, respectively with circular openings 26, and these end walls carry the tubular portions 27 which extend outwardly away from the interior of the chamber 16 through openings 28 which are formed in the end walls of the housing 1, as is particularly apparent from FIG. 4. Thus, by the placing of the tubular portions 27 at the ends of the cylinder 15 through the openings 28 the housing 1 supports the charging chamber 16 and of course all of the structure connected thereto. It is to be noted that the electrode 17 together with the cylinder 15 form a unitary sub-assembly of the unit 7.

The tubular portion 27 at each end of the cylinder 15 surrounds one end of the tubular extension 29 which thus extends into the tubular portion 27, and the tubular extension 29 is made of a material which has almost no electrical conductivity and which is very highly resistant to any current leakage from its surface, such a material being, for example, polyvinyl chloride. The open end of the extension 29, which is to say the end distant from the cylinder 15, is provided with threads 30, and a plug 31 is screwed into the end of each extension 29 for closing the latter, this plug 31 also being made of a material such as polyvinyl chloride. The inner surface of the tubular extension 29 is formed with a continuous groove 32 of any haphazard meander-shaped configuration so as to very greatly increase the surface area at the interior of the tubular extension 29. At its inner end portion which is received in the tubular portion 27, the extension 29 carries a metal cylinder 33. In order to fix each extension 29 to the portion 27 which carries the same a screw 34 extends through each portion 27 and the tubular end of the extension 29 which it surrounds, as shown at the lower part of FIG. 4, and the screw 34 engages at its inner end the metal cylinder 33 so as to electrically connect the latter to the soldering lug 35 which places the cylinder 33 in an electrical circuit which is described below.

The support means for supporting the discharge wire 24 is connected to the ends thereof, and this support means includes at each end of the wire 24 an elongated wire 36 formed at its end with a loop onto which an end of the wire 24 is hooked or otherwise joined, and a portion of the supporting wire 36 extends through a central bore 37 formed in the plug 31, the bore 37 being of a small diameter so that the wire 36 has only a very slight clearance in the bore 37, and the wire 36 is maintained under tension so that the charging electrode 24 is also tensioned and extends parallel to the axis of the cylinder 15 through the interior of the chamber 16. At the exterior of the plug 31 the support wire 36, which together with the tubular extension 29 forms the structure of the support means at one end of the wire 24, is connected to a soldering lug 39 by a screw 38, so that through the soldering lug 39 it is possible to locate the wire 36, and thus the charging electrode 24, in an electrical circuit which is described below.

The drum 2 is grounded, and also the cylinders 33 are grounded through the soldering lugs 35. Although a pair of soldering lugs 39 may be provided, actually there may be only one soldering lug 39 and at the other end of the cylinder 15 the wire 36 is connected to the plug 31 simply by a screw 38. The developing electrode 17 is connected to a source of voltage through the soldering lug 23 and through the soldering lug 39 the charging electrode 24 is connected to a source of high voltage.

As was indicated above, the distance between the charging electrode 24 and the developing electrode 17 is relatively small but on the other hand is great enough so that the distance between the opening 19 and the charging electrode 24 is determined by the potential difference between the high voltage of the electrode 24 and the voltage of the developing electrode 17, this distance being great enough so that there will be no arcing between the electrodes 17 and 24. In the example illustrated in the drawings and described above this distance may be on the order of 10–50 mm.

Arcing between the supporting wire 36 which is also at high voltage and the grounded cylinder 33, which cooperates with the wire 36 to form an electrical filter in a manner described below, is avoided in spite of the relatively small distsance between the high voltage wire 36 and the cylinder 33 by making the wire 36 of a diameter larger than the diameter of the wire 24 so that there will be no discharge at the wire 36 and instead the discharge will occur only at the charging electrode 24.

The structure of the treating unit 8 corresponds to that of the treating unit 7 described above. In particular the treating unit 8 includes the developing electrode 18 which is located subsequent to the developing electrode 17 in the direction of travel of the band 4. The charging electrode 25 of the treating unit 8 is constructed in the same way and is supported in the same way as the charging electrode 24 of the treating unit 7 so that the electrode 25 will also serve to charge particles of the aerosol developer.

The connection of the developing electrodes **17** and **18** as well as the charging electrodes **24** and **25** to their voltage sources is illustrated in FIG. 5. The wiring diagram of FIG. 5 shows three assemblies **40**, **41** and **42** of which the assembly **40** serves to control the supply of voltage to the developing electrodes **17** and **18** while the assemblies **41** and **42** serve respectively to supply and control the supply of voltage to the charging electrodes **24** and **25**.

The assembly **40** includes a transformer **45** connected to the source of alternating current **43** and **44**, this source simply being the lines which are supplied by a public utility with a suitable alternating current. The secondary of the transformer **45** is connected to the input of a full wave rectifier **46**, and the output of the rectifier **46** is connected to the conductors **50** and **51**. Through the conductors **50** and **51** the output of the rectifier **46** is connected to the filter formed by the resistor **49** and the condensers **47** and **48**. The conductor **50** is grounded while the conductor **51** carries a negative D.C. voltage. Connected in parallel between the conductors **50** and **51** are a pair of potentiometers **52** and **54** which can be adjusted independently of each other through the adjustable contacts **53** and **55**, respectively. These adjustable contacts **53** and **55** are respectively connected to the developing electrodes **17** and **18**, and by suitably adjusting the potentiometers it is possible to provide at each of the electrodes **17** and **18** a voltage of between 0 and —400 volts. In general the potential of the developing electrodes **17** and **18** will be of the same polarity as the charge carried by the photoconductive material of the band **4**.

The assemblies **41** and **42** are essentially of the same construction and they are connected through the conductors **56** and **57** to the alternating current lines **43** and **44**. Each of these assemblies includes a high voltage transformer. Thus, the assembly **41** includes the high voltage transformer **58** while the assembly **42** includes the high voltage transformer **59**, and the primary of the transformer **58** is provided with a plurality of tap points **60** adapted to be selectively engaged by the turnable contact **62** which is connected to the conductor **57** while the primary of the transformer **59** is provided with the tap points **61** adapted to be selectively placed in engagement with the movable contact **63** which is also connected to the conductor **57**. The secondary of the transformer **58** is connected to the rectifier **64** and the smoothing condenser **66** while the secondary of the transformer **59** is connected to the rectifier **65** and the smoothing condenser **67**. The D.C. voltage conductors **68** and **69** of the assembly **41**, which are connected to the secondary of the transformer **58** and which include the protective resistors **72** and **73**, respectively, are connected to the reversing switch **76**, **77**. In the same way, the secondary of the transformer **59** is connected to the D.C. voltage conductors **70** and **71** which are provided with the protective resistors **74** and **75**, respectively, and which are connected to the reversing switch **78**, **79**. The reversing switch **76**, **77** includes the stationary contacts **76***a* and **77***a*, and the stationary contacts **76***b* and **77***b*, while the switch **78**, **79** includes the contacts **78***a*, **79***a* and the contacts **78***b* and **79***b*, as illustrated in FIG. 5. All of the contacts **76***a*, **77***a*, **78***a*, **79***a* are connected to the grounded conductor **80**, while the contacts **76***b*, **77***b* are connected through the conductor **81** to the charging electrode **24** and the contacts **78***b*, **79***b* are connected through the conductor **82** to the charging electrode **25**. The movable switch members of the switch **76**, **77** are interconnected mechanically by the element **83** so that the conductors **68** and **69** will be connected simultaneously either to the contacts **76***a*, **77***b*, respectively, as shown in FIG. 5, or to the contacts **76***b*, **77***a*, respectively. In the same way the movable switch members of the switch **78**, **79** are interconnected by the element **84** and will connect the conductors **70** and **71** simultaneously either to the contacts **78***a*, **79***b*, respectively, as shown in FIG. 5, or to the contacts **78***b*, **79***a*, respectively. These switches **76**, **77** and **78**, **79** can be controlled through relays, if desired. In the position of the parts shown in FIG. 5, the charging electrodes **24** and **25** have a high positive voltage, while when the switches are reversed the charging electrodes will have a high negative voltage. The magnitude of the positive or negative voltage of the charging electrodes can be adjusted by adjusting the movable contacts **62** and **63** of the primary windings of the transformers **58** and **59** to engage selected tap points, and in this way the voltage may be adjusted in a stepwise manner to a value of, for example, between 0 and 7000 volts.

While the charging electrodes **24** and **25**, on the one hand, and the developing electrodes **17** and **18**, on the other hand, are shown as being connected to separate voltage sources, it is of course also possible to connect all of these electrodes to a common voltage source.

The above-described structure of FIGS. 1–5 operates in the following manner:

The band **4** which carries the photoconductive material with the latent electrostatic image which is to be developed has its photoconductive material provided with a negative charge, for example, and this material will first reach the treating unit **7**. Simultaneously, the treating unit **7** is provided from the supply means **12** through the conduits **11**, **9**, **9***a*, **9***b*, **9***c* with a continuously flowing stream of aerosol developer which when passing through the charging chamber **16** to the opening **19** will pass the charging electrode **24** so that the particles of the aerosol developer will be charged in the manner of corona discharge. The charged particles then reach and pass through the opening **19** into the space between the drum **2** and the developing electrode **17** so as to engage the photoconductive material on the band **4** which is in this space, and thus the developing particles will become deposited upon the photoconductive material with the density of the deposition of particles on the photoconductive material being determined by the density and distribution of the charge of the photoconductive material, and thus the developing particles will be distributed on the photoconductive material in accordance with the distribution of the charge in the photoconductive material which conforms to the latent electrostatic image, and since the developing particles are visible they render the image visible.

During development of positive pictures the particles of the aerosol developer become deposited upon the negatively charged portions of the photoconductive material, and in this case the switch **76**, **77** will have the position shown in FIG. 5, the charging electrode **24** having under these conditions a positive voltage of, for example, 4000 volts, so that the particles of the aerosol developer are positively charged. Under these conditions it is desirable to provide the developing electrode **17** with a small negative voltage.

In order to provide negative pictures the negative voltage of the charging electrode **17** is greatly increased by shifting the adjustable member **53** of the potentiometer **52** upwardly, as viewed in FIG. 5, so that the electrode **17** will have a negative voltage on the order of, for example, 400 volts, and the switch **76**, **77** of FIG. 5 is reversed so that the movable contacts thereof engage the contacts **76***b* and **77***a*, and in this case the aerosol particles are negatively charged. Under these conditions the developer particles deposit themselves upon the portions of the photoconductive material of the band **4** which are not charged.

Of course, if the photoconductive material is originally provided with a positive charge, then all of the signs of all of the voltages, or in other words the polarities of all of the voltages, are reversed.

The electrical field of the charging electrode **24** has no undesirable influence on the electrical field between

the developing electrode **17** and the band **4** during deposition of the developing particles thereon, in spite of the small distance between the charging electrode and the band **4**, as a result of the shielding action of the developing electrode **17**. On the other hand, the location of the charging electrode **24** close to the opening **19** provides the advantage of requiring the particles of the aerosol developer to travel through an extremely short distance between the area where they are charged and the photoconductive material on which they become deposited so that undesirable deposits of developing particles in passages, tubes, or the like along which they might otherwise be required to travel are avoided and in this way loss of developer is also very greatly reduced.

At the beginning of the blowing of the stream of aerosol developer particles into the charging chamber **16** there will indeed be deposition of some of the developer particles on the inner surface of the chamber **16**, which is to say at the inner surface of the cylinder **15**. However, inasmuch as this inner surface is not electrically conductive, the particles which become deposited at the inner surface of the chamber **16** have the same polarity as the charging wire **24**, so that further deposition beyond an initial slight deposition of particles is prevented and the intensity of the electrical field between the charging electrode **24** and the wall **15** of the chamber **16** drops, while, on the other hand, the intensity of the electrical field between the charging electrode **24** and the limits **20** and **21** of the opening **19** maintains its full magnitude. Under the influence of the strong electrical field the charged particles of the aerosol developer pass through the opening **19** with a relatively high speed so that undesired deposition of the developer particles on the strips **20** and **21** remains very small, although such deposition might ordinarily be expected.

Inasmuch as the stream of particles of the developer, after passing through the opening **19**, becomes divided into a pair of opposed stream portions, the speed of movement of the stream of particles drops off in the space between the band **4** and the developing electrode **17**, so that the length of time during which the developer particles remain in the developing space between the electrode **17** and the band **4** is increased and thus the possibility of providing the desired deposition of particles on the photoconductive material is greatly increased.

Moreover, the division of the stream of particles into a pair of oppositely directed stream portions, one of which moves counter to the direction of movement of the band **4** and the other of which moves in the same direction of the band **4**, provides the result that part of the particles have their speed of movement added to the speed of movement of the band **4** while another part has its speed subtracted from the speed of movement of the band **4**, and thus any lack of uniformity in the development, even at high operating speeds, is greatly canceled out.

In the space within the tubular extensions **29** there are practically no charged aerosol particles, and in any event only a relatively small number of charged particles tend to move toward the interiors of the extensions **29**. As was pointed out above, the conductor **36**, in addition to supporting the wire **24**, acts with the grounded cylinder **33** as an electrical filter, and this electrical filter will cause deposition of particles on the inner surface of the cylinder **33**. In other words, because of the electrical field between the wire **36** and the cylinder **33** the relatively small amount of particles which tend to move into the extensions **29** are deposited on the inner surface of the cylinder **33**, so that in this way the elements **33** together with the elements **36** act as electrical filters. As a result of the meander-shaped configuration of the inner surface of the extension **29** the possibility of current leakage between the place where the wire **36** passes through the opening of the plug **31** and the metal cylinder **33** is very greatly reduced as a result of the large surface area between the cylinder **33** and the opening **37**, so that even after a long period of operation the inner surface of the plug **31** remains completely clean. In this way the high degree of insulation is maintained, and such a high degree of insulation is required because of the high voltage of the wires **36** and **24**.

The liquid developer particles which become deposited upon the developer electrode **17** can, with the arrangement shown in the drawing, drop off the lower edge of the developing electrode **17** without in any way undesirably influencing the band **4** and in particular the photoconductive material thereon. In particular, the liquid particles which become deposited on the upper half of the developing electrode **17** can flow along the surface of the electrode **17** through the opening **19** into the chamber **16** where they fall back through the conduits **9*a***, **9*b***, **9*c*** to the supply means **12**. Any aerosol developer which becomes located in the housing **1**, in the free inner space thereof after passing through the developing chamber between the electrode **17** and the band **4**, are removed through the suction conduit **85** (FIG. 1) which is connected with an unillustrated suction pump and an electrical filter which is also connected thereto and which is not illustrated so that after being sucked out of the interior of the housing **1** through the conduit **85** the particles will be separated from the stream by the electrical filter.

After the photoconductive material together with a portion of the band **4** has passed through the developing chamber defined between the electrode **17** and the drum **2**, this portion of the photoconductive material and the band **4** will reach the treating unit **8** which operates in the same way as the treating unit **7** and which serves to complete the developing process which has already been carried out with the treating unit **7**. Thus, for example, any lack of uniformity in the development of the picture during treatment with the unit **7**, which may occur during high speed operation, is compensated for by the treating unit **8**. Picture portions which are not completely developed in the first treatment by the unit **7** are completely developed in the treatment at the second unit **8**. In this way even during high speed travel of the band **4**, which is desired in the interest of profitable operation of the apparatus, it is possible to obtain faultless pictures.

Inasmuch as the treating units **7** and **8** are respectively provided with separate structures for charging the particles of the aerosol developer, it is possible to charge the developers of the two treating units in different ways. Thus, it is possible, for example, to charge the particles of the aerosol developer of the treating unit **7** to a lesser extent than the particles of the aerosol developer of the treating unit **8**. It can happen that in the treating unit **7** the deposition of the developer particles on the photoconductive material neutralizes the charge of the latter to such an extent that further deposition of aerosol particles in the developing space between the electrode **17** and the drum **2** on the photoconductive material will not take plcae. However, when such a portion of the photoconductive material reaches the treating unit **8** under the conditions where the developer particles of the latter unit are charged to a greater extent, then even with the same potential on the charging electrode, as a result of the higher charge of the particles there will be a further deposition of developing particles on the photoconductive material so that the contrast of the picture will be improved. It is also possible to operate the structure in such a way that the developer particles are not charged in the treating unit **7** and are charged only in the treating unit **8**, so that during movement of the photoconductive material through the developing chamber of the treating unit **7** the uncharged developer particles will become deposited only at the edges of the image portions of the latent electrostatic image in the photoconductive material, while these areas of the image whose edges receive the uncharged particles from the unit **7** are filled in with deposition of the charged particles at the unit **8**. This type of treatment provides a particularly uniform development.

The above-described and illustrated arrangement of electrodes also makes it possible to develop the same

images with two different aerosol developers or with other developers.

An embodiment which can accomplish this result is shown in FIG. 6. In FIG. 6, instead of a common supply means **12** for the developer, there are a pair of supply means **86** and **87** which are completely separate from each other so that they can supply entirely different materials. Each of the units **86** and **87** is provided with devices for atomizing the colored solution so as to provide fine aerosol particles, as described above. The supply means **86** is connected through the conduit **9** and its branches with the treating unit **88**, while the supply means **87** communicates through the conduit **10** and its branches with the treating unit **89**. The conduits **9** and **10** are provided with branches in the same way as described above and shown in FIG. 2. The treating units **88** and **89**, whose structure is described in greater detail below, correspond in their operation to the treating units **7** and **8** of FIGS. 1–5. In the event that the supply means **86** and **87** supply different aerosol developers, the photoconductive layer on the band **4** will receive first one aerosol developer and then a second, different aerosol developer. Thus, it becomes possible to use differently colored developers to obtain predetermined colored tones in the developed pictures.

It is also possible to supply through the separate supply means **86** and **87** colored aerosol developers which react with each other after becoming deposited upon the photoconductive material.

The second aerosol which is supplied from the supply means **87** can also be used for the purpose of providing the photoconductive material with a treatment subsequent to the development thereof by the unit **88**. Although an electrophotographic picture developed with an aerosol developer of suitably colored particles will normally require no additional fixing, since the deposition of the particles on the photoconductive material provides a fixed development, it can happen that in certain special cases it will be desired to provide an additional fixing for the developed picture, and in this case the developing which takes place in the treating unit **88** can be fixed in the treating unit **89**, so that the treating unit **89** is provided from the supply means **87**, not with a suitably colored aerosol developer, but rather with an aerosol carrying particles of a fixing solution which become deposited upon the photoconductive layer. Moreover, the treatment of the band **4** by the unit **89** can be by way of a suitable vapor rather than an aerosol. The treatment provided in the unit **89** may be for the purpose of transferring the developed pictures so as to make reproductions thereof.

The valves **13** and **14** also make it possible to use the treating units **7** and **8** of FIG. 1 or **88** and **89** of FIG. 6 alternatively. Thus, it is, for example, possible to use the structure shown in FIG. 5 with an arrangement as shown in FIG. 6 according to which the supply means **86** provides an aerosol developer which is suitable for positive developments in order to provide positive pictures while the supply means **87** provides an aerosol developer which is particularly suitable for negative development providing negative pictures. In this case the treating unit **88** would be used only when developing positive pictures and the treating unit **89** would be used only when developing negative pictures, and thus it becomes possible with such an arrangement to change over very quickly and conveniently between positive and negative development.

The treating units **88** and **89** are of the same construction, and the details of the treating unit **88** are shown in FIGS. 7 and 8. In FIGS. 7 and 8 those parts which have substantially the same construction as the parts of FIGS. 1–4 are indicated with the same reference characters.

The treating unit **88** differs from the treating unit **7** in that the charging chamber **16** instead of being defined by a cylindrical wall means **15** is defined by a wall means **90** also made of electrically non-conductive material but having a rectangular or square cross-section. Moreover, the opening in the developing electrode **17**, instead of being in the form of a narrow gap **19**, is in the form of a larger opening **91**, and the electrode **17** carries a wire mesh **92** which extends across the opening **91**. Moreover, instead of a simple charging wire **24** to form the charging means, the charging means of this embodiment includes a plurality of pointed electrodes **93** which are preferably supported by a common carrier **95** which is supported at its ends in exactly the same way that the wire **24** is supported so that in this way high voltage can be supplied to the several electrodes **93**. Thus, with this embodiment also the wires **36** will cooperate with the metal cylinders **33** to provide an electrical filter for the developer particles.

The charging of the developer particles with the charging means **93** takes place by a corona discharge at the tips of the pointed electrode **93**. Also in this embodiment the electrical field of the electrodes **93** has no undesirable influence on the electrical field directed toward the band **4** from the developing electrode **17** as a result of the shielding action of the mesh **92**.

Instead of providing the electrode **17** with a wire mesh **92** it is also possible to simply provide the electrode **17** with small openings extending therethrough to provide the same action. Also, it is possible to arrange within the charging chamber **16** a plurality of rows of pointed electrodes **93** located adjacent each other.

As was pointed out above, the treating unit **89** correspond in its construction to the treating unit **88**, and the treating unit **89** includes the pointed charging electrodes **94** which are arranged and operate in the same way as the pointed charging electrodes **93** of the treating unit **88**.

It is possible to make the cylinder **15** or the enclosure **90** of metal, but in this case the inner surface of the cylinder **15** or the enclosure **90** should be coated with a layer of electrically non-conductive material.

If the developing device, instead of being provided with two or more treating units **7**, **8** or **88**, **89**, is to have only a single treating unit, even in this case it is of advantage to provide the single treating unit with the structure described above.

Although the structure described above and shown in the drawing is designed for development of latent electrostatic images in photoconductive material, the feature of providing a plurality of treating units with separate conduits for supplying developer thereto is also of advantage in structures which are used to develop latent images in semi-conductor material.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of electrophotography differing from the types described above.

While the invention has been illustrated and described as embodied in electrophotographic developers, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. In an apparatus for developing an electrostatic image formed in a photoconductive material, in combination, a developing electrode formed with an elongated opening of

relatively small width through which aerosol developing particles pass to the photoconductive material; and a charging electrode located adjacent said developing electrode in alignment with said opening for charging the aerosol particles as they advance toward said opening to pass therethrough, the distance between said electrodes being great enough to prevent arcing therebetween.

2. In an apparatus for developing an electrostatic image formed in a photoconductive material, in combination, a developing electrode formed with a cutout which passes therethrough; a mesh carried by said developing electrode in said cutout thereof and defining openings through which particles of an aerosol developer pass to the photoconductive material; and a charging electrode located adjacent said developing electrode in alignment with said cutout thereof for charging the particles of the aerosol developer as they advance toward said mesh to move through said openings thereof, the distance between said electrodes being great enough to prevent arcing therebetween.

3. In an apparatus for developing an electrostatic image formed in a photoconductive material, in combination, a developing electrode adapted to be located adjacent the photoconductive material and formed with an opening through which particles of an aerosol developer pass toward the photoconductive material; and an elongated charging wire forming a charging electrode and located adjacent said developing electrode in alignment with said opening thereof, said charging wire charging the particles of the aerosol developer as they advance toward said opening and said wire extending perpendicularly to the path of movement of the particles of the developer toward said opening.

4. In an aparatus for developing an electrostatic image formed in a photoconductive material, in combination, a developing electrode located adjacent the photoconductive material and formed with an opening through which particles of an aerosol developer pass toward the photoconductive material; and charging means located adjacent said developing electrode in alignment with said opening thereof for charging the particles of the aerosol developer as they advance toward said opening, said charging means being spaced from said electrode by a distance great enough to prevent arcing between said charging means and said electrode and said charging means including a plurality of pointed electrodes and a carrier common to and carrying said pointed electrodes.

5. In an apparatus for developing an electrostatic image formed in a photoconductive material, in combination, a developing electrode located adjacent the photoconductive material and formed with an opening through which particles of an aerosol developer pass toward the photoconductive material; means located adjacent said developing electrode and forming a chamber which communicates with said opening thereof, the particles of the developer passing from the interior of said chamber through said opening of said developing electrode toward the photoconductive material; and charging means located in said chamber in alignment with said opening of said charging electrode adjacent the latter for charging the developer particles as they advance toward said opening, said charging means being spaced from said developing electrode by a distance great enough to prevent arcing therebetween.

6. In an apparatus for developing an electrostatic image formed in a photoconductive material, in combination, a developing electrode located adjacent the photoconductive material and formed with an opening through which particles of an aerosol developer pass toward the photoconductive material; wall means located adjacent said developing electrode and defining a chamber the interior of which communicates with said opening, said wall means having at least an inner surface which is made of an electrically non-conductive material; and charging means located in said chamber adjacent said developing electrode in alignment with the opening thereof for charging particles of the aerosol developer as they advance from the interior of said chamber through said opening, the distance between said charging means and said developing electrode being great enough to prevent arcing therebetween.

7. In an apparatus for developing an electrostatic image formed in a photoconductive material, in combination, a developing electrode located adjacent the photoconductive layer and formed with an opening through which particles of an aerosol developer pass toward the photoconductive material; wall means located next to said developing electrode and formed with an opening aligned with and located next to the opening of said electrode so that developer particles within the chamber defined by said wall means pass through both of said openings toward the photoconductive material, the opening of said wall means being larger than the opening of said electrode; and charging means located in said chamber in alignment with said opening adjacent to said developing electrode for charging the developer particles as they advance toward said openings, the distance between said charging means and said developing electrode being great enough to prevent arcing therebetween.

8. In an apparatus for developing an electrostatic image formed in a photoconductive material, in combination, a developing electrode located adjacent the photoconductive material and formed with an opening through which particles of an aerosol developer pass toward the photoconductive material; a charging chamber located adjacent said developing electrode and formed with an opening aligned with and located next to the opening of said developing electrode, the aerosol developer passing from the interior of said charging chamber through said openings to the photoconductive material, said developing electrode having along at least part of the edge of said opening thereof a flange which extends into said opening of said charging chamber; and a charging electrode located in said charging chamber adjacent said developing electrode in alignment with said openings for charging the particles of the developer as they advance toward said openings, the distance between said electrodes being great enough to prevent arcing therebetween.

9. In an apparatus for developing an electrostatic image formed in a photoconductive material, in combination, a developing electrode located adjacent the photoconductive material and formed with an opening which passes through the developing electrode; a charging chamber connected to and forming a unit with said developing electrode, said charging chamber being formed with an opening aligned with the opening of said developing electrode so that an aerosol developer in said charging chamber can pass through said openings to the photoconductive material; and a charging electrode located in said charging chamber adjacent said developing electrode and in alignment with said openings for charging particles of the aerosol developer as they advance toward said openings, the distance between said electrodes being great enough to prevent arcing therebetween.

10. In an apparatus for developing an electrostatic image formed in a photoconductive material, in combination, a developing electrode located adjacent the photoconductive material and formed with an opening which passes through the developing electrode; a charging chamber located next to said developing electrode and formed with an opening aligned with the opening of said developing electrode; a supply pipe communicating with said charging chamber at the lowest elevation thereof for delivering an aerosol developer to the interior of said chamber to pass through said openings to the photoconductive material; and a charging electrode located in said chamber adjacent said developing electrode and in alignment with said openings for charging particles of the aerosol developer as they advance through the interior of said chamber toward said openings.

11. In an apparatus for developing an electrostatic image formed in a photoconductive material, in combination, a developing electrode located adjacent the photoconductive material and formed with an opening; a charg-

ing chamber located next to said electrode and formed with an opening aligned with said opening of said electrode; a plurality of supply pipes communicating with the interior of and distributed along said chamber for supplying to the latter an aerosol developer which passes from said pipes into said chamber and from the interior of the latter through said openings to said photoconductive material; and a charging electrode located in said chamber adjacent said developing electrode and in alignment with said openings for charging the particles of the developer as they advance through the interior of said chamber toward said openings, the distance between said electrodes being great enough to prevent arcing therebetween.

12. In an apparatus for developing an electrostatic image formed in a photoconductive material, in combination, a developing electrode located adjacent the photoconductive material and formed with an opening; a charging chamber located next to said developing electrode and formed with an opening aligned with said opening of said elcetrode so that an aerosol developer in said chamber can pass through said openings to said photoconductive material, said chamber carrying a pair of tubular extensions which communicate with the interior of said chamber; and charging means located in the interior of said chamber adjacent said developing electrode in alignment with said openings for charging particles of the aerosol developer as they advance toward said openings, said charging means passing through said extensions and the distance between said charging means and developing electrode being great enough to prevent arcing therebetween.

13. In an apparatus for developing electrostatic images formed in a photoconductive material, in combination, a developing electrode located adjacent the photoconductive material and formed with an opening; a charging chamber located next to said electrode and formed with an opening aligned with said opening of said electrode so that particles of an aerosol developer in said chamber can pass through said openings to the photoconductive material; charging means located in said chamber adjacent said electrode and aligned with said openings for charging the developer particles as they advance toward said openings, the distance between said charging means and said electrode being great enough to prevent arcing therebetween; and support means supporting said charging means and forming part of an electric filter structure.

14. In an apparatus for developing an electrostatic image formed in a photoconductive material, in combination, a developing electrode located adjacent the photoconductive material and formed with an opening; a charging chamber located next to said developing electrode and formed with an opening aligned with said opening of said electrode, said chamber carrying a pair of tubular extensions which communicate with the interior of said chamber; an elongated charging electrode located in said chamber adjacent said developing electrode and aligned with said openings for charging particles of an aerosol developer as they advance toward said openings; a pair of electrically conductive portions respectively passing through said tubular extensions and supporting said charging electrode; and a pair of metal cylinders surrounding said electrically conductive portions and carried by said extensions in the interior thereof.

15. In an apparatus for developing an electrostatic image formed in a photoconductive material, in combination, a developing electrode located adjacent the photoconductive material and formed with an opening; a charging chamber located next to said developing electrode and formed with an opening aligned with said opening of said developing electrode so that an aerosol developer in said charging chamber can pass through said openings to the photoconductive material; a pair of tubular extensions carried by said chamber and communicating with the interior thereof, said extensions each having an inner surface or meander-shaped configuration; a charging electrode located in said chamber adjacent said developing electrode and aligned with said openings for charging the particles of the developer as they advance toward said openings, the distance between said electrodes being great enough to prevent arcing therebetween; and electrically-conductive support means supporting said charging electrode and passing through the interior of said tubular extensions.

16. In an apparatus for developing an electrostatic image formed in a photoconductive material, in combination, a stationary developing electrode located adjacent the photoconductive material and having directed toward the latter a surface extending downwardly from an upper edge of said developing electrode to a lower edge thereof, said electrode being formed intermediate said upper and lower edges thereof with an elongated opening passing through said electrode and extending in the same general direction as said upper and lower edges thereof; wall means located adjacent said developing electrode and defining a chamber the interior of which communicates with said elongated opening, said wall means having at least an inner surface which is made of an electrically non-conductive material; an elongated charging means located in said chamber spaced from said wall means thereof adjacent said developing electrode in alignment with said opening thereof for charging particles of aerosol developer as they advance from the interior of said chamber through said opening, the distance between said charging means and said developing electrode being great enough to prevent arcing therebetween; and supply conduit means communicating through a lower portion of said wall means with the interior of said chamber for supplying thereto liquid developer particles, so that any of said particles which collect on said surface of said developing electrode between said upper edge and opening thereof can return through said opening back into said chamber to said supply conduit means while any particles which collect on said electrode between said opening and lower edge thereof can drip from said lower edge thereof, so as to prevent excessive accumulation of developer particles on said surface of said electrode.

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