

[54] **DEVELOPMENT APPARATUS FOR LATENT ELECTROSTATIC IMAGES**

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[58] Field of Search **118/629, 637; 117/17.5; 250/49.5 ZC**

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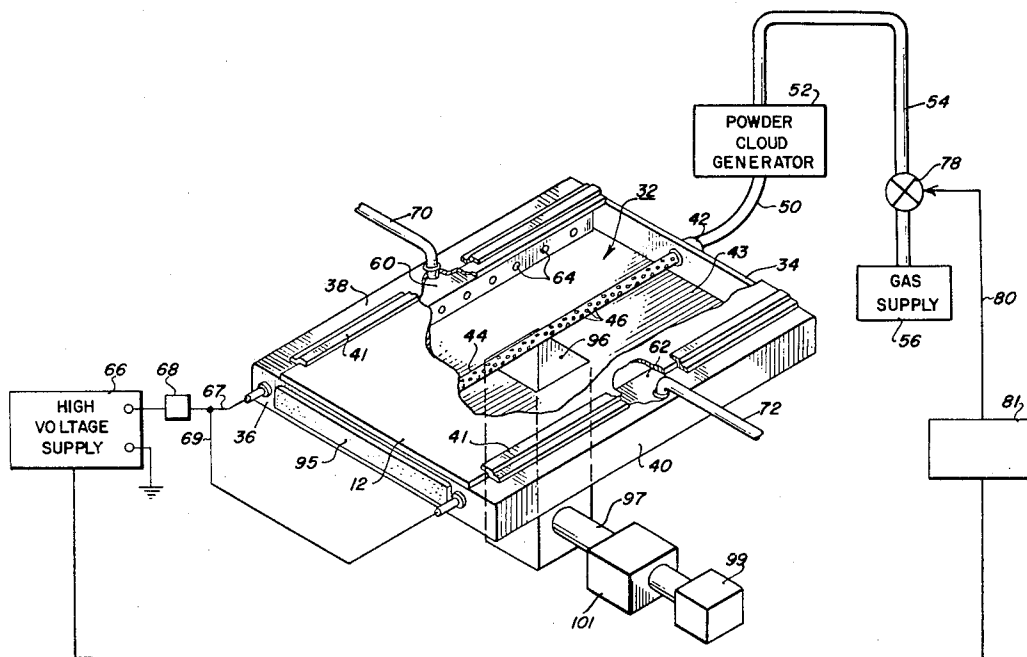
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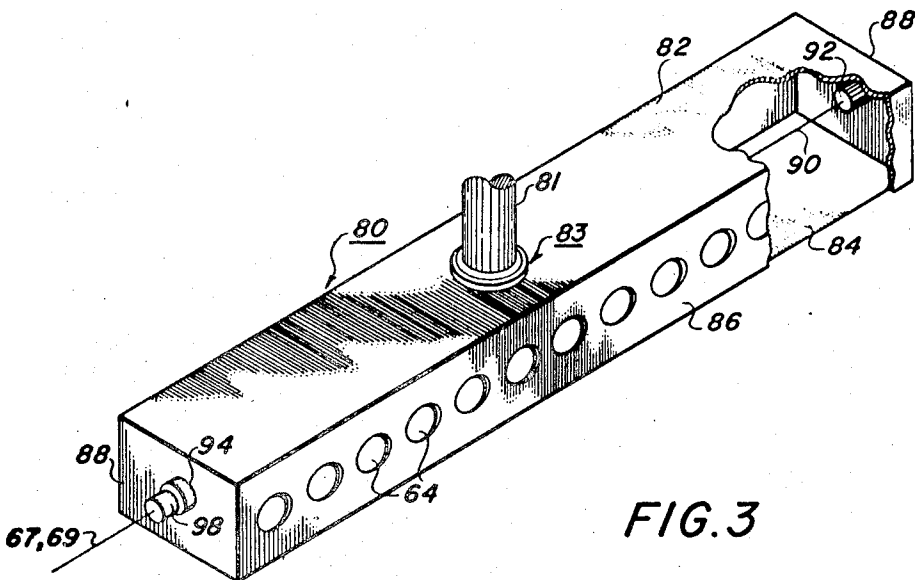
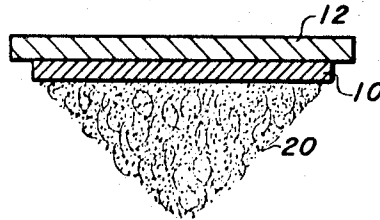
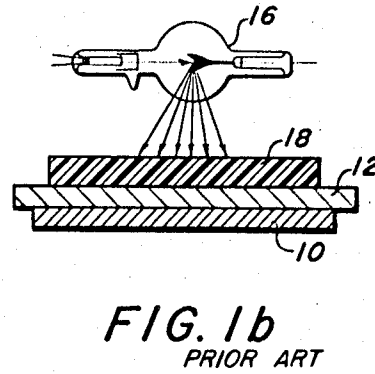
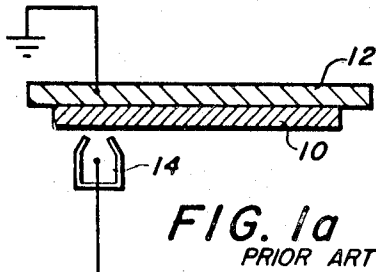
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ABSTRACT

Powder cloud development apparatus for developing latent electrostatic images comprising ion emitters adjacent a chamber area into which developer particles are introduced. The ion emitters are enclosed and have a plurality of apertures formed on an enclosing wall facing towards the chamber. When the ion emitters are energized, gas introduced therein is ionized and the ions are forced out through the apertures into the chamber area, thereby charging the developer particles. The developer particles are prevented from entering the ion emitters through the apertures by maintaining a pressure differential between the ion emitters and the chamber.

4 Claims, 6 Drawing Figures





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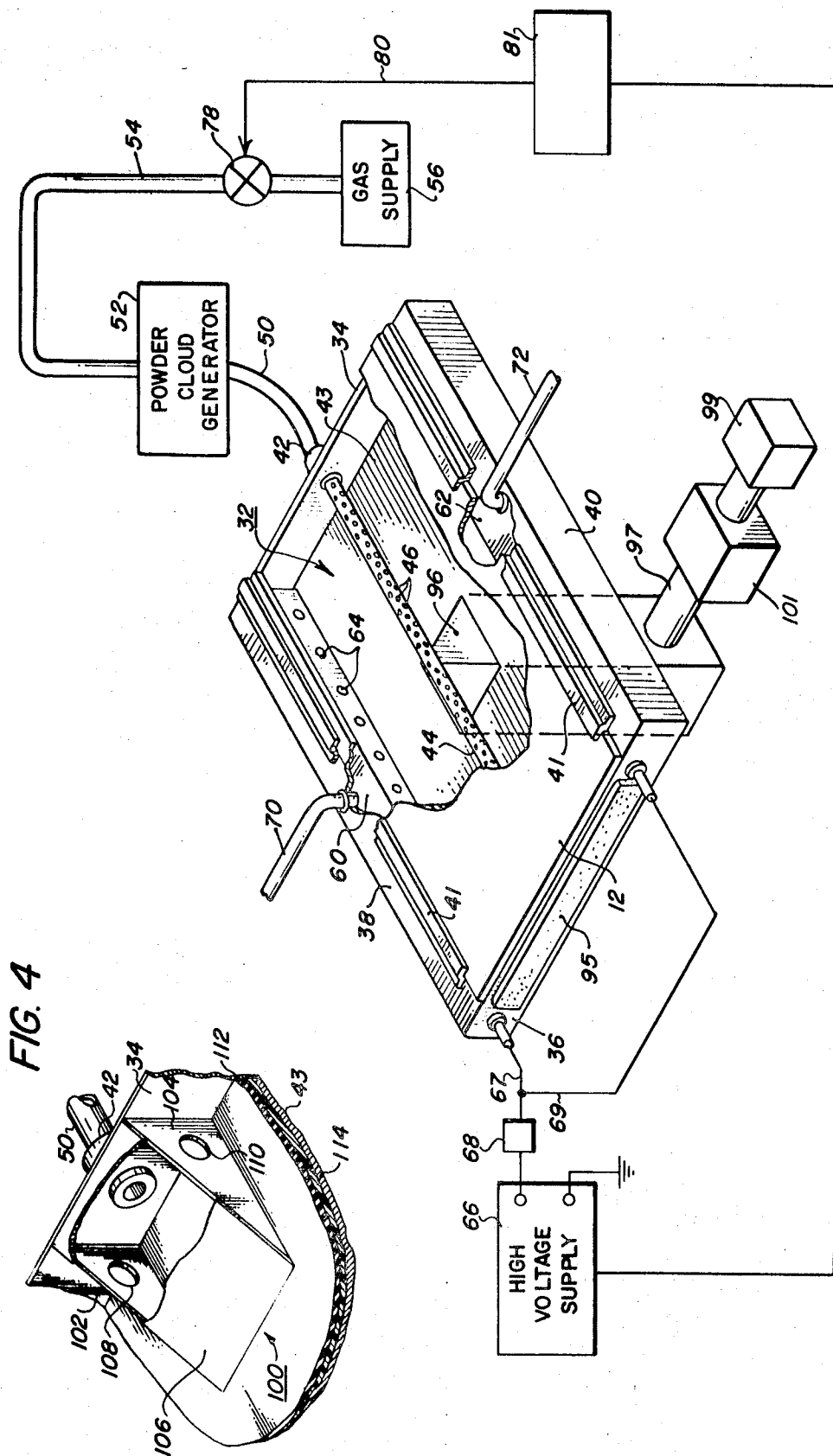


FIG. 2

DEVELOPMENT APPARATUS FOR LATENT ELECTROSTATIC IMAGES

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of U.S. Application Ser. No. 832,697, filed June 12, 1969, and now abandoned.

BACKGROUND OF THE INVENTION

Xeroradiography, as disclosed in U.S. Pat. No. 2,666,144, is a process wherein an object is internally examined by subjecting the object to penetrating radiation. A uniform electrostatic charge is deposited on the surface of a xerographic plate and a latent electrostatic image is created by projecting the penetrating radiation, such as X-rays or gamma rays, through the object and onto the plate surface. The electrostatic latent image may be made visible by contacting the latent electrostatic image on the plate surface with fine powdered particles electrically charged opposite to the latent electrostatic image pattern on the plate. The visible image may be viewed, photographed or transferred to another surface where it may be permanently affixed or otherwise utilized. The entire processing is dry and no darkroom is necessary.

Xeroradiography in recent years has been utilized to detect breast cancer in women. The resolving power of the xeroradiographic plate has been found to exceed that of the conventional film utilized in roentgenography. Tests with wire mesh have shown that using standard roentgenographic film, one begins to lose detail with a mesh of 180 lines to the inch while a mesh of 1,200 lines to the inch can be recorded on a xeroradiographic plate.

In examination of breasts wherein soft tissue comprises most of the breast area, xeroradiography, or xeromammography, provides greater resolving power than the conventional roentgenographic film and greater image detail is achieved. A wide range of contrast is seen on the xeroradiographic plate as compared to the conventional roentgenographic films so that all the structures of the breast from the skin to the chest wall and ribs may be well visualized. Besides providing better contrast, xeromammography detects small structures like tumor calcification and magnifies them more than conventional film, is quicker, less expensive, gives greater detail and requires less radiation than prior X-ray techniques.

The technique of powder cloud development, as disclosed in U.S. Pat. No. 2,711,481, has been utilized to develop xeroradiography plates. This development technique is preferred in xeromammography because discontinuities in the object being examined are readily developed. The charged surface of the plate is disposed facing a chamber area in which a cloud of powder particles are introduced. The particles may be charged opposite to the polarity of the charge on the plate so that the particles deposit upon the surface of the plate in a positive image configuration due to the electrostatic forces of the electrostatic latent image on the plate acting on the charged particles in the powder cloud. Various prior art techniques for charging the powder cloud include turbulently flowing the powder particles in air through a nozzle tube or the like to triboelectrically charge the particles or by passing the particles through a corona discharge area comprising a fine needle or fine wire and a grounded electrode as disclosed in U.S. Pat. No. 2,725,304. The corona method of charging the particles has been found to provide more uniform charging of the powder cloud, thereby producing high-resolution images when the xerographic plate is developed. Prior art devices which utilized a corona discharge to charge the powder particles, such as that set forth in U.S. Pat. No. 2,725,304, have disadvantages associated therewith. The powder particles, when introduced into the chamber and charged, may accumulate around the corona discharge electrode such that the electrode ceases to charge powder particles entering the chamber area. Although the electrode may be cleaned periodically to remove the powder particles therefrom, the necessity of cleaning the corona electrode is

time consuming, the cost and complexity of development is increased, and the particles may deposit on the person manually cleaning the electrode.

SUMMARY OF THE INVENTION

The present invention provides improved apparatus for developing electrostatic latent images, and, in particular, relates to powder cloud development apparatus for developing electrostatic latent images formed in the xeroradiography process. The invention provides ion emitters which isolate the high-voltage wire therein from the area where the powder cloud is introduced into the chamber. The ion emitters are enclosed and have a plurality of openings along one sidewall. When gas introduced into the ion emitters is ionized, the ions are injected into the chamber area through the holes. The ions are forced into the chamber area by maintaining a positive pressure difference between the ion emitters and the chamber. The high-voltage wire is not exposed to the charged developer particles and the possibility of blocking or clogging the wire is minimized.

It is, therefore, an object of the present invention to provide improved apparatus for developing electrostatic latent images.

It is a further object of the present invention to provide improved apparatus for developing latent electrostatic images in a powder cloud development chamber.

It is still a further object of the present invention to provide novel apparatus for developing electrostatic latent images in a powder cloud development chamber wherein a ionizing high-voltage wire is isolated from the chamber area in which the powder cloud is introduced and wherein a positive pressure is maintained between the ion-emitting and chamber areas to force the generated ions into the chamber area.

It is an additional object of the present invention to provide new improved development apparatus for use in xeromammography.

DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention as well as other objects and further features thereof, reference is made to the following description which is to be read in conjunction with the accompanying drawings wherein:

FIGS. 1a-1c schematically indicate the process of xeroradiography as carried out in the prior art;

FIG. 2 is an isometric drawing of development apparatus according to the invention with a cutaway section to show greater detail of the apparatus;

FIG. 3 is an isometric view of the ion-emitting devices utilized in the invention with a cutaway section to show greater detail of the apparatus; and

FIG. 4 is an isometric view of a baffle arrangement which may be utilized with the present invention with a cutaway section to show greater detail of the apparatus.

DESCRIPTION OF A PREFERRED EMBODIMENT

Referring now to FIGS. 1a-1c three stages A, B, C of the xeroradiography process utilizing powder cloud development is shown. Stage A represents the charging or sensitizing step in the process; stage B, the exposure step; and stage C represents the development step. At step or stage A, as shown in FIG. 1a, a plate member comprising a photoconductive insulating layer 10 overlying conductive backing member 12 is made sensitive by placing an uniform electrostatic charge on its surface. In this figure, charging is accomplished by the action of corona discharge to the surface of layer 10 while backing member 12 may be held at ground potential. Corona discharge electrode 14 may be made up of one or a number of fine strands of wire to which a corona emitting voltage is supplied from a high-voltage source, and the electrode may include a control electrode to limit, or make more uniform, the potential placed on the plate. Other ways may be used to apply electrostatic charge to the surface of layer 10.

Once the plate member has been sensitized, it is ready for the exposure step which is shown in FIG. 1b. Penetrating radiation from a source 16 is projected to penetrate an object 18 resting on backing member 12 on which is coated layer 10. The exposure step creates on the surface of layer 10 an electrostatic latent image of the radiograph of the object being examined. It is to be noted that object 18 may rest on or be spaced from layer 10 and then exposed directly to the penetrating radiation. Alternately, object 18 may be exposed through backing member 12 if the backing member is selected to be transparent to the penetrating radiation.

The plate member is then ready for the development step shown in FIG. 1c where its photoconductive surface 10 is exposed to a cloud of powder particles 20 of the type disclosed in the aforementioned U.S. Pat. No. 2,725,304. The particles disclosed therein are capable of accepting an electrostatic charge thereon and are capable of being dispersed in air. As will be described in more detail hereinafter in reference to FIGS. 2 and 3, the present invention provides novel means for charging the particles in powder cloud 20 which provides advantages over the prior art methods described hereinabove. The electrostatically charged particles deposit on the surface of layer 10 in image configuration due to the electrostatic forces of the latent image on surface 10 acting on the charges on the particles comprising powder cloud 20. The source of penetrating radiation 16 may comprise a conventional X-ray source although other radiation sources having the property of generating radiation which penetrates objects to be examined may be utilized. The plate may be a conventional plate used in the art of xeroradiography and includes plates generally used in xerographic apparatus. It should be noted that the novel development apparatus of the present invention, as described hereinafter, may be utilized to develop electrostatic latent images which have been deposited upon any suitable substrate by any known technique. For example, an electrostatic charge pattern may be deposited upon a substrate which has an insulating layer thereon by the electrostatic printing technique disclosed in U.S. Pat. No. 3,289,209. In the exposure step wherein object 18 rests on backing member 12, the backing member may be any conductive material, such as aluminum which is transparent to penetrating radiation from source 16. In the X-ray mode, layer 10 should be composed of a material which absorbs penetrating radiation when exposed thereto and becomes conductive and which in the absence of penetrating radiation is a good insulator. Such a material includes materials which generally have a resistivity on the order of greater than 10^{12} ohm-cm. in the absence of radiation and a resistivity in the presence of penetrating radiation of about 10^3 or 10^4 ohm-cm. lower than in the absence of such radiation. A layer of selenium around 160 microns thick has been successfully utilized. Many additional materials may be employed in accordance with this invention such as amorphous or vitreous selenium, sulphur, anthracene, certain materials of a class generally known as phosphors, the binder plate layers as disclosed in U.S. Pat. No. 3,121,006, the glass binder plate layers as disclosed in U.S. Pat. No. 3,151,982, and the like. It is to be understood, of course, that the additional materials listed are only illustrative of the many that may be employed, and it is intended to encompass within the scope of this invention those materials having the insulating and conductive characteristics as described above. The discussion recited hereinabove has been given for background purposes since the subject matter of the present invention is directed to apparatus for developing an electrostatic latent image once formed upon a suitable substrate. In the following discussion, it will be assumed that an electrostatic latent image has been formed upon a suitable substrate in accordance with the radiation pattern which has penetrated through an object being examined. The development method hereinafter described may be utilized in xeroradiography, xeromammography or other processes wherein electrostatic latent images, deposited upon a suitable substrate, are to be developed.

Referring now to FIG. 2, there is shown an isometric drawing of the developing apparatus according to the present invention with a cutaway section that shows greater details of the apparatus. An enclosed area or chamber 32, is formed by a rectangular shaped frame member comprising end walls 34 and 36, sidewalls 38 and 40, bottom support 43 and the plate described with reference to FIG. 1 hereinabove. The plate member is introduced to the frame member with layer 10 facing or disposed towards the chamber area 32. The chamber may be enclosed by sliding the plate towards end wall 34 through guide brackets 41. A nozzle 42 is inserted into chamber 32 through an aperture in end wall 34. Attached to one end of nozzle 42 and extending lengthwise into chamber 32 is a cylindrical member 44 having a plurality of apertures or holes 46 thereon. A tube 50 connects the other end of nozzle 42 to powder cloud generator 52 as shown. The powder cloud generator 52 is connected to a source of pressurized gas 56, such as air, via tube 54. Located within chamber 32 and affixed to sidewalls 38 and 40 are ion emitters 60 and 62, respectively. As will be described in more detail hereinafter with reference to FIG. 3, ion emitters 60 and 62 are generally enclosed, except for a plurality of apertures or holes 64 on the side thereof facing towards the chamber area 32. The ion emitters 60 and 62, which include a high-voltage wire for ionizing the gas therein, are energized by known means, such as from high-voltage supply 66. In the embodiment shown, the current generated by the high-voltage supply is time delayed by delay unit 68 before energizing the high-voltage ionizing wires. A source of pressurized gas, not shown, is connected to ion emitters 60 and 62 via tubes 70 and 72, respectively.

In operation, the powder cloud is generated by means of pressurized gas source 56 and powder cloud generator 52 by well-known techniques such as that disclosed in U.S. Pat. No. 2,824,813. In this technique, pressurized gas from source 56 forces finely divided particles into a cloud, the cloud exiting through tube 50. The powder cloud generated in powder cloud generator 52 is transported by tube 50 to nozzle 42 whereby the powder cloud is introduced into chamber 32. As shown in FIG. 2, the nozzle 42 is connected to a cylindrically shaped member 44 having a plurality of holes 46 thereon. When the gas supply 56 is activated, the powder cloud is introduced through nozzle 42 into member 44 and dispersed into the chamber area 32 through the holes 46 therein, thereby providing a uniform powder cloud throughout the chamber area 32. The powder particles in the powder cloud are charged as follows: the high-voltage wires mounted in emitters 60 and 62 are connected to high-voltage supply 66 through delay means 68 via conductors 67 and 69. The polarity of the high-voltage supply utilized is dependent upon the type of charged ions to be emitted into the chamber area. Generally, the powder cloud is charged with a polarity opposite to the polarity of the electrostatic image formed on layer 10. Delay means 68, of conventional form, may be included to delay the current to the high-voltage ionizing wires to enable the powder cloud to be dispersed into the chamber area 32. This minimizes the possibility that the ions emitted by ion emitters 60 and 62 will discharge the sensitized plate before the powder cloud in the chamber is charged. Therefore, as shown in FIG. 2, gas supply 56 is allowed to flow to powder cloud generator 52 when servo valve 78 is opened by a control signal appearing on conductor 80, via voltage attenuator 81, the control signal being generated before the high-voltage ionizing wires are energized. The high-voltage wires are energized to a potential sufficient to ionize the gas supplied by tubes 70 and 72 to the ion emitters 60 and 62, respectively. A positive pressure differential is maintained between the ion emitters and the chamber area 32 by controlling the pressure of gas supply 56 and the gas supplied to the ion emitters. The ions generated in the ion emitters 60 and 62 are, due to the positive pressure differential, forced through the holes 64 into the chamber area 32, mixing with the powder cloud introduced into the chamber by member 44, thereby producing a substantially uniformly charged powder cloud. Member 44

may also be constructed in various shapes and sizes other than that shown. It should be noted that member 44 may be omitted and the powder cloud uniformly introduced into chamber area 32 by utilizing a plurality of baffles in the chamber to direct the powder cloud entering from nozzle 42 to various portions of the chamber. Although two ion emitter devices are described in the embodiment shown in FIG. 2, it should be apparent that a lesser or greater number of the devices may be utilized. For example, ion emitter 62 may be omitted, nozzle 42 entering chamber area 32 through end wall 34 as shown or through sidewall 40. If desired, the development apparatus may be modified so that the powder cloud is supplied to the chamber area 32 through both walls 34 and 40. A third ion emitter may be affixed to end wall 36 by appropriate modification of the apparatus. It should also be noted that the ion emitters may be affixed to the frame member external to the chamber area, the wall to which the ion emitter is affixed having holes thereon to allow the ions to enter the chamber area.

The positive pressure differential maintained between the ion emitters and the chamber area 32 prevents the powder particles from entering the ion emitters, thereby preventing contamination or clogging of the high-voltage ionizing wires. A pressure differential in the range from about 4 inches of water to about 18 inches of water has been successfully utilized. However, to insure that the developer particles do not enter the ion emitters, the positive pressure differential between the ion emitter housing and the development chamber per se should be substantially fully established at the time when the powder cloud is introduced into the development chamber. Otherwise, the flow rate of the powder cloud would be sufficient to cause the developer particles to enter the ion emitters and the objectives of the present invention would be defeated.

To enable the aforementioned pressure differential to be established, there is provided porous pads 95, adjacent at least a portion of the side of development area 32, securely mounted to the external sides of the development chamber, and adapted to allow the passage of air therethrough. Additionally, the pressure differential simultaneously established between the development chamber and the external environment outside the chamber prevents pressure buildup in the chamber which would cause seal leakage with attendant leakage of the developer particles to the internal portions of the surrounding enclosure. Pads 95 are of limited porosity such that while airflow can be maintained therethrough, developer particles cannot pass therethrough into the external environment.

At the bottom of the development chamber, in the bottom wall thereof, there is a port 96 through which unused developer particles are withdrawn during the purge cycle. Port 96 is connected to conduit 97 which, in turn, is connected to developer particle filter means 101 and blower means 99. Inside conduit 97 there is a flapper valve (not shown) hinged for rotational movement between a closed position and an open position. At the beginning of the purge cycle, the flapper valve is moved into the open position such that the blower is placed in communication with the development chamber through filter means 101, conduit 97 and port 96, whereby unused developer particles, entrained in the air passing through pads 95, is withdrawn from the development chamber. At the end of the purge cycle, the valve is released from its open position and returns to the closed position, for example, under the urging of a spring (not shown).

The ions emitted from emitters 60 and 62 and the electrostatic latent image on layer 10 may be of opposite polarity, whereby the charged developer particles are caused to deposit on layer 10 in an arrangement exactly corresponding to the electrostatic image originally thereon, to form an image of a first, or positive, sense. Alternately, the ions emitted by emitters 60 and 62 and the electrostatic latent image on layer 10 may be of like polarity, whereby the particles are repelled from the charged portions of layer 10, depositing on the

uncharged portion of layer 10 to yield an image of a second, or negative, sense. The image sense, therefore, is determined by the polarity of high-voltage source 66. For example, if the polarity of source 66 is positive, positive ions will be emitted from emitters 60 and 62 into the chamber area 32 and a positive image will be developed if the electrostatic latent image on layer 10 is of a negative polarity. If the polarity of source 66 is negative, negative ions will be emitted into chamber area 32, thereby developing a negative image. It should be noted that by adjusting the magnitude of the ion current, the contrast of the developed image can be controlled.

Referring now to FIG. 3, there is shown in more detail a view of the ion emitters which may be utilized in the present invention.

The ion emitters comprise an enclosed rectangular shaped housing, generally indicated by the reference numeral 80, and includes top wall 82, bottom wall 84, sidewall 86 and end walls 88. A high-voltage wire 90, comprising any suitable noncorrosive material such as stainless steel, platinum alloy, etc., is stretched between terminal blocks 92 and 94 of suitable insulating material which are affixed to the sidewalls 88. Mounted to insulator 94 is a conducting member, or finger, 98 which is electrically connected to high-voltage wire 90 and disposed for engagement with high-voltage supply 66 (FIG. 2). The opposite end of the conducting wire 90 is connected to insulator block 92. Walls 82 and 84 are grounded. A plurality of apertures or holes 64 are formed on sidewall 86, the holes being spaced apart from each other in accordance with any desired pattern. The hole diameter is preferably less than 0.1 inches and a successful embodiment of the present invention utilized 0.043-inch-diameter holes. A tube 81, corresponding to tube 70 or 72 in FIG. 2, is connected to housing 80 at 83 in any suitable manner, the gas introduced by tube 81 being ionized when a source of high-voltage potential is connected to finger 98. The location 83 at which the tube 81 is connected to housing 80 is not critical although preferably the connection is located approximately in the middle of top wall 82 to obtain uniform charging of the developer cloud particles. The ion emitter described hereinabove is illustrative of a conventional ionizing device modified in accordance with the teachings of the present invention. Ion, or corona, generating devices are well known in the art, and, in accordance with the teachings of the present invention, are modified to include ion-emitting holes or apertures on one sidewall thereof and to connect a gas-supplying tube thereto to provide the novel features of the present invention.

As set forth hereinabove, the cylindrical member 44 shown in FIG. 2 may be replaced by baffles to uniformly mix the powder cloud entering the chamber with the ions generated by ion emitters 60 and 62. A simplified representation of a baffle arrangement which may be utilized in the present invention is shown in FIG. 4. A baffle 100, having triangularly shaped sides 102 and 104 and rectangularly shaped side 106 is mounted flush with end wall 34. The baffle encloses the aperture in wall 34 through which nozzle 42 enters chamber 32. Sides 102 and 104 of baffle 100 have apertures 108 and 110, respectively, therein. In operation, as the powder cloud enters the area enclosed by the baffle, the particles are deflected and directed into the chamber area 32 through apertures 103 and 110. The baffle is positioned and the powder cloud velocity is preferably chosen so that the powder cloud particles pass in front of ion emitters 60 and 62 along substantially the whole length thereof. This arrangement allows the mixing of the ions and powder cloud particles to be substantially complete. If the mixing is not complete, layer 10 may be randomly discharged or the image charge neutralized.

The configurations shown in FIGS. 2 and 4 may be further modified by the addition of a biased collector plate 112 to the bottom of the chamber. The biased plate 112 is insulated from the frame of the development unit by providing an insulating plate 114 between the bottom of the chamber and the biased plate 112. The biased plate 112 aids in controlling the contrast of the developed image on layer 10 and controls image edge

deletion. It is believed that the biased plate gives the developer particles a vertical velocity component normal to layer 10 so as the particles approach the image areas they tend to penetrate the image field, including the area of the image corresponding to the edges. The biased plate 112 also acts as a collector for positively charged developer particles if it is biased negatively and collects negatively charged developer particles if it is charged positively. As described hereinabove with reference to the polarity of voltage source 66, the polarity of the biased plate is determined by the type of image to be developed, either a positive or negative. Generally, the polarity of the biased plate 112 is the same as the polarity of voltage source 66. The magnitude of the bias applied to plate 112 may vary from about 2,000 to about 6,000 volts. The biased plate 112 must be cleaned periodically to remove the collected developer particles therefrom.

The invention as described hereinabove provides novel apparatus for developing electrostatic latent images and in particular, a novel powder cloud development technique. The prior art powder developing units are handicapped by the fact that when the powder cloud particles are charged by corona wire or needles, the wires become contaminated and clogged by the charged particles, reducing the efficiency of the units and eventually preventing image development. Maintenance and cleaning of the prior art corona elements is time consuming and expensive. The present invention eliminates the problems described hereinabove by utilizing ion emitters wherein the ionizing high-voltage wires are enclosed and isolated from the developer particles introduced into the chamber, the developer particles being prevented from entering the emitters by the techniques described hereinabove. The generated ions and the developer particles introduced into the chamber are uniformly mixed by the apparatus of the present invention, thereby providing images with greater contrast and higher resolution.

What is claimed is:

1. Apparatus for developing a latent electrostatic image on a surface comprising:
a chamber comprising a plurality of walls,

support means for supporting a surface having a latent electrostatic image thereon, the support means being arranged to position said surface with the latent electrostatic image facing inwardly to said chamber,

means for supplying a cloud of developer particles to said chamber through a first of said chamber walls, and

ion emitter means positioned at a second of said chamber walls for supplying ions to said chamber under pressure, said ion emitter means comprising an enclosed housing including a wall substantially the length of said chamber having a plurality of holes thereon, at least one wire attached between end walls of said housing, means for maintaining a potential difference across said wire and means for introducing pressurized gas into said ion emitter housing, whereby the gas introduced into said housing is ionized, the ions escaping through said holes to charge said developer particles.

2. The apparatus as defined in claim 1 wherein the pressure in said housing is greater than the pressure in said chamber, whereby the pressure differential forces said ions through said holes into said chamber.

3. Apparatus for developing a latent electrostatic image of a first polarity on a surface, said apparatus comprising:

a chamber comprising a plurality of walls;

support means for supporting said surface with its latent electrostatic image facing said chamber;

means for supplying a cloud of developer particles to said chamber through a first of said chamber walls; and

ion emitter means positioned at a second of said chamber walls for supplying ions to said chamber under pressure, said ions charging said developer particles to either said first polarity or to a second polarity opposite to said first polarity, said developer particles charged to said second polarity being attracted to said surface for developing said image.

4. The apparatus as defined in claim 3 wherein said ions are supplied to said chamber at a pressure greater than the chamber pressure.

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