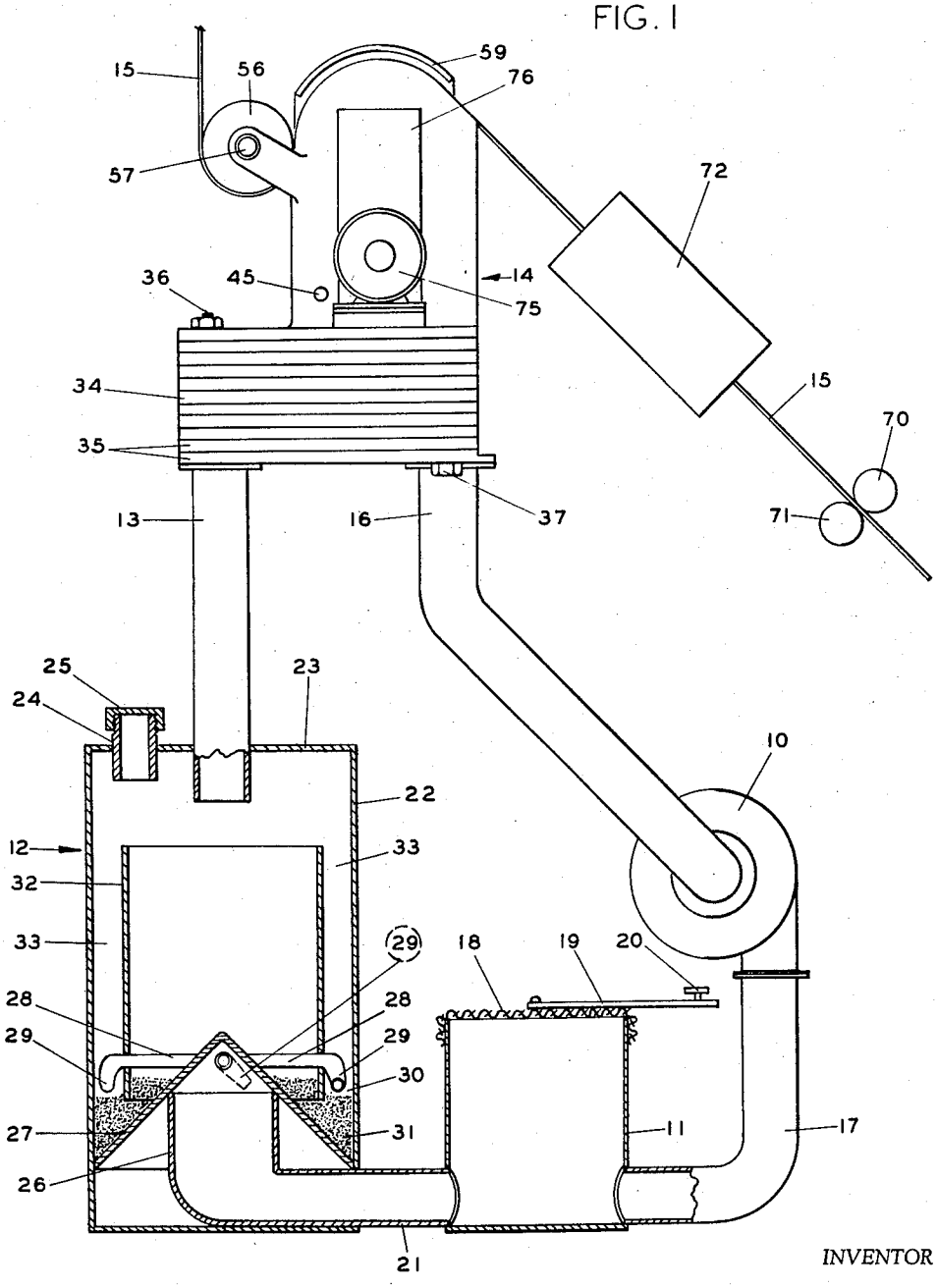
March 15, 1960 C. F. CARLSON 2,928,575

ELECTROSTATIC IMAGE DEVELOPMENT

Original Filed Oct. 12, 1953 4 Sheets-Sheet 1

FIG. 1



INVENTOR

Chester F. Carlson

BY Stanley Z Cole

ATTORNEY

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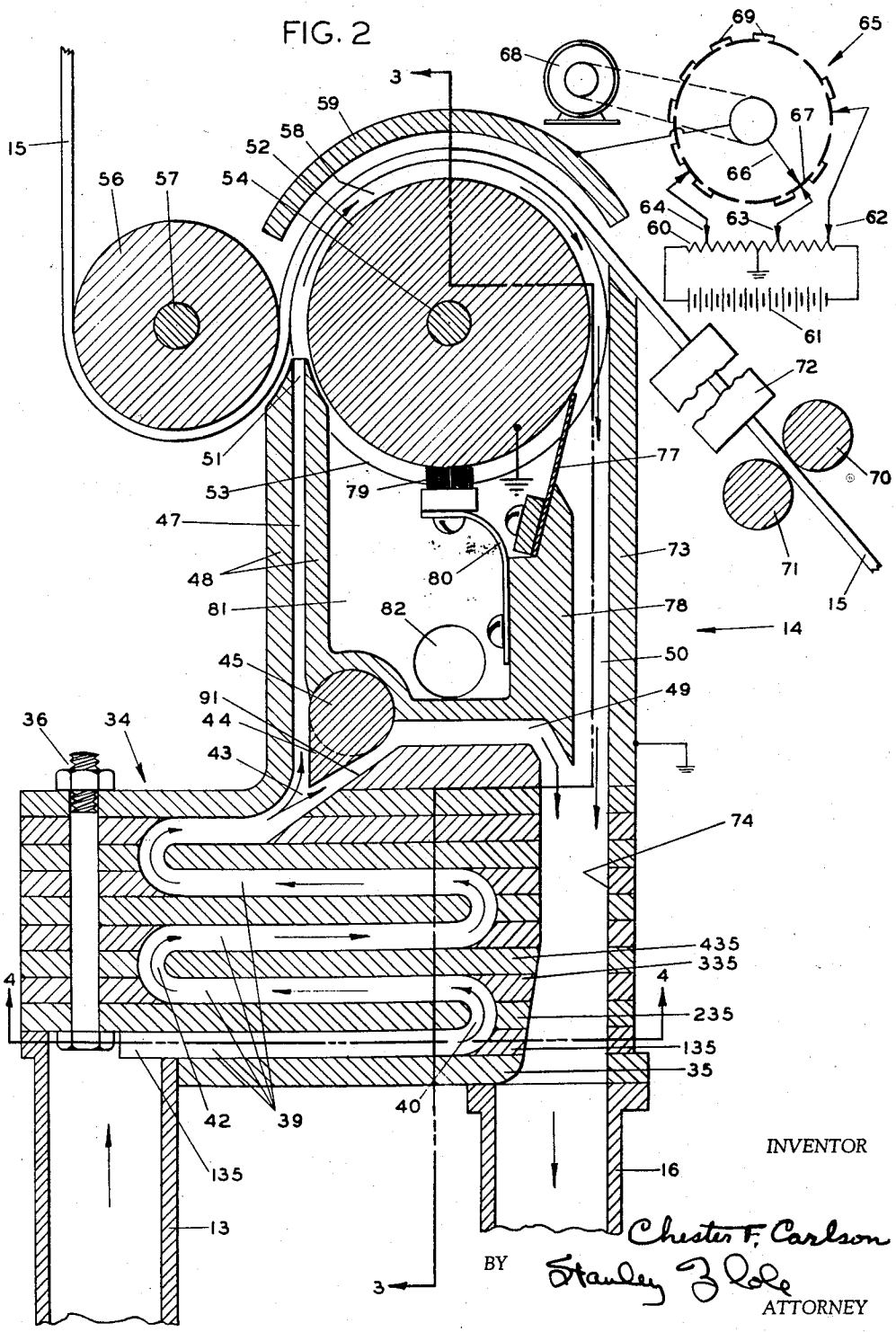
ELECTROSTATIC IMAGE DEVELOPMENT

Original Filed Oct. 12, 1953 4 Sheets-Sheet 2

FIG. 2



INVENTOR

Chester F. Carlson

BY Stanley Z. Lobe

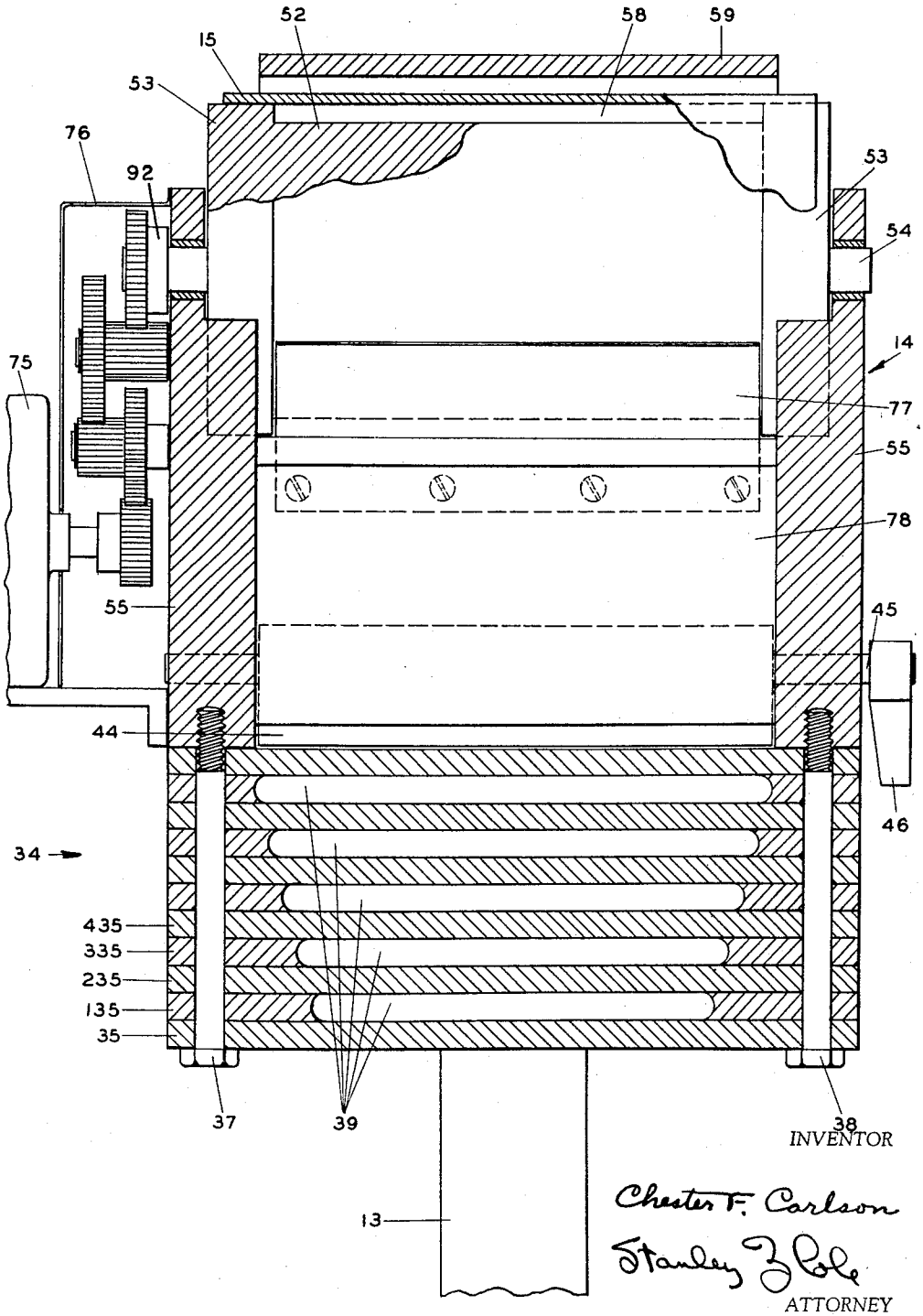
ATTORNEY

March 15, 1960 C. F. CARLSON 2,928,575

ELECTROSTATIC IMAGE DEVELOPMENT

Original Filed Oct. 12, 1953 4 Sheets-Sheet 3

FIG. 3



INVENTOR

Chester F. Carlson

Stanley Z. Cole

ATTORNEY

March 15, 1960 C. F. CARLSON 2,928,575

ELECTROSTATIC IMAGE DEVELOPMENT

Original Filed Oct. 12, 1953 4 Sheets-Sheet 4

FIG. 4

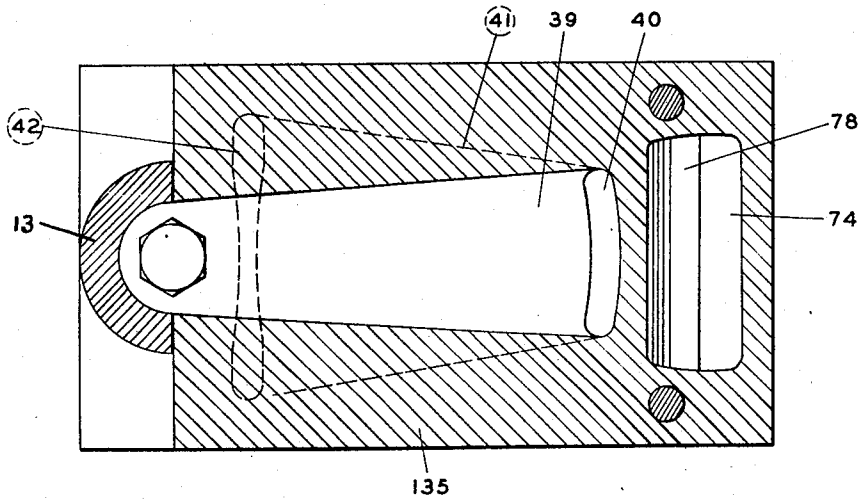


FIG. 5

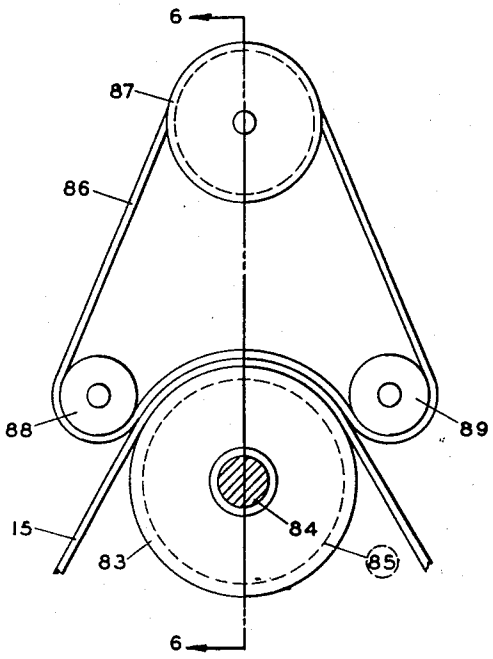
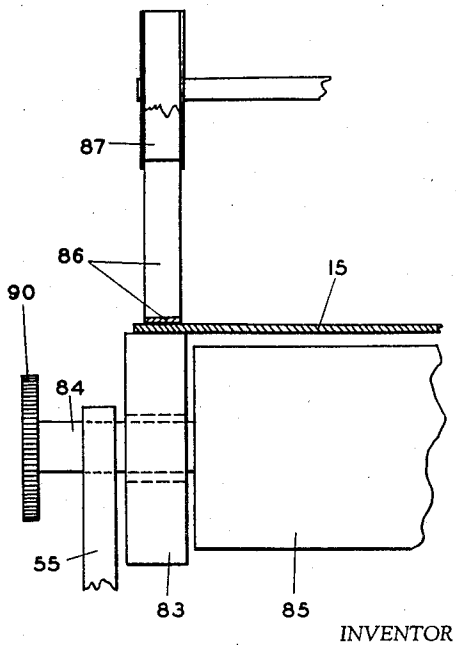


FIG. 6



INVENTOR

Chester F. Carlson

BY Stanley Z. Cole

ATTORNEY

United States Patent Office 2,928,575 Patented Mar. 15, 1960

2,928,575

ELECTROSTATIC IMAGE DEVELOPMENT

Chester F. Carlson, Pittsford, N.Y., assignor, by mesne assignments, to Haloid Xerox Inc., Rochester, N.Y., a corporation of New York

Original application October 12, 1953, Serial No. 385,314, now Patent No. 2,876,737, dated March 10, 1959. Divided and this application July 30, 1958, Serial No. 751,940

11 Claims. (Cl. 222—193)

This invention relates to apparatus for the development of electrostatic images.

This is a division of my co-pending application, Serial No. 385,314, filed October 12, 1953 and now Patent No. 2,876,737 and entitled "Electrostatic Image Development."

In electrostatic image processes, such as Electron Photography disclosed in Carlson Patent 2,221,776, issued November 19, 1940, and Electrophotography disclosed in Carlson Patents 2,297,691, issued October 6, 1942, and 2,357,809, issued September 12, 1944, the electrostatic latent image which has been formed on a surface is developed by bringing a finely-divided material, such as powder, or a liquid mist, adjacent to the image to produce a deposition of material on the surface or on a closely-adjacent surface to form a visible image. In some instances the powder may be sprinkled or tumbled over the surface to be developed and excellent results have been obtained by a cascading method using a two component powder-carrier mixture as described, for example, in Wise Patent 2,618,552, issued November 18, 1952. Such methods have been most successful where contrasting images are to be developed, such as black lines or letters on white background. Where continuous tone images are to be developed, and also where large dark areas are present and even in some cases where high definition of line images is required it has been found that the most sensitive development method is one in which an air-suspension of finely-divided material, such as powder or liquid mist, is blown past the image surface. An important further measure of control of development can be obtained in such cloud development apparatus by providing a development electrode facing the image surface, as disclosed in application for U.S. Letters Patent, Serial No. 500,207, filed August 27, 1943, by Chester F. Carlson, now U.S. Patent 2,551,582, issued May 8, 1951, for Printing and Developing Solvent Images, and in divisional application Serial No. 166,411, filed June 6, 1950, for Electrophotography, now Patent No. 2,690,394. The development electrode can be electrically biased to a desired potential or series of potentials during development in order to control the deposition of material.

With liquid developers, such electrodes may be substantially self-cleaning or self-draining. However, with powder clouds it has been found that powder accumulates quite rapidly on the development electrode necessitating frequent shut-downs for cleaning, or requiring awkward wiping mechanisms.

One feature of the present invention comprises an improved developing mechanism for developing electrostatic images on flexible sheet material by means of powder clouds and development electrodes and in which convenient cleaning means are provided for the development electrode. The development mechanism preferably comprises cylindrical surfaces around which a web of sheet material can be drawn and a cylindrical development electrode which can be rotated inside the channel formed in

the web, and cleaning means co-operating with the development electrode.

Another feature of the present invention comprises the powder cloud generating and transportating means whereby a powder cloud is continuously generated by air or other gas currents at low pressure. A further feature includes separatory mechanisms and devices in the powder cloud transporting system by which large particles, conglomerates and agglomerates are separated and diverted from the main developer stream of the powder cloud.

Other features include means to spread a powder cloud stream into a layer wide enough for development of the entire width of a web and means to prevent loss or leakage of powder cloud.

While the invention is especially applicable to powder cloud development certain parts of the apparatus and certain features thereof are also applicable to other cloud development methods, such as liquid mist development.

Further aspects and novel features of the invention will be apparent from the following detailed description of certain embodiments thereof, and by reference to the appended drawings in which:

Figure 1 is an elevation, partly in section, of a powder cloud development apparatus for developing electrostatic images on flexible sheets or webs;

Figure 2 is a vertical section through the development head;

Figure 3 is a section on the line 3—3 of Figure 2;

Figure 4 is a section on the line 4—4 of Figure 2;

Figure 5 is a detail of a modified guide for the sheets or webs to be developed; and

Figure 6 is a section on the line 6—6 of Figure 5.

Referring to Figure 1 the apparatus comprises a blower 10 for producing a low pressure air or gas stream, an air vent cylinder 11, and a powder cloud generator 12 for introducing a powder suspension into the air stream. A powder cloud conduit 13 leads from generator 12 to development head 14 through which a web or sheet 15 carrying an electrostatic image is drawn for development by the powder cloud. The air stream and residual powder remaining in the stream after passing through the developing head is returned to the intake part of blower 10 by conduit 16.

Blower 10 may comprise an electric motor-driven rotary vane-type blower such as is used in household vacuum cleaners of various sizes. In one embodiment a 200 watt blower generated a powder cloud stream adequate for developing an 8½ inch width of image surface at web speeds of 20 to 60 feet per minute.

The air stream from blower 10 passes through conduit 17 into the base of air vent chamber 11 which consists of an upright cylinder having a closed bottom and a porous filter cloth or other air filter layer 18 secured over the open top of the chamber. A plate or disk 19 is pivotally mounted at one edge of the top of cylinder 11 to be swung over the top by handle 20 to close a portion of the filter surface and increase the air resistance of the vent. It will be apparent that such powder as collects on the inside of filter 18 can fall by gravity to the bottom of cylinder 11 where it can again be picked up by the air stream. Except for the small proportion of air which passes out through the filter the remainder of the air stream and returning powder are carried through cylinder 11 to conduit 21 which leads into the base of powder cloud generator 12.

Powder cloud generator 12 comprises an upright cylinder 22 which is closed at the bottom except for air inlet conduit 21 which enters at the base of the side wall. The top of the cylinder 22 is closed by a top wall 23 and powder cloud conduit 13 passes vertically through the center of top wall 23. A powder filling passage 24

fitted with a screw cap seal **25** is also provided in the top wall **23** beside conduit **13**.

Inside the base of generator **12** inlet conduit **21** extends to a point near the center where it turns upward to provide a central vertical standpipe portion **26**. A wall comprising an inverted cone **27** is secured over the top of standpipe portion **26** and extends out to the side wall **22** to which it is secured. The apex of the cone is at the axis of cylinder **22** and since the wall of the cone slopes downward and outward to cylindrical wall **22** it forms an annular and substantially V-shaped trough **30** in which powder may settle from the upper portions of the generator. It is preferred that the cone wall make an angle with the central axis of 45 degrees or less to facilitate sliding of powder toward the outer edges of the trough.

Several tubes **28** are secured in the cone near its apex and extend horizontally and radially to positions spaced circumferentially inside wall **22** where they are provided with constricted nozzles **29** pointed slantingly downward to eject air into V-shaped powder channel **30**. The nozzles are all pointed in a clockwise direction as viewed from above so as to produce a circular drifting or swirling of the powder **31** in channel **30** as it is picked up by the air streams ejected from nozzles **29**. From two to eight or more nozzle tubes **28** are mounted in cone **27** to conduct the air and any entrained powder from standpipe **26** into the powder cloud generating section of the generator. The total cross section of the tubes **28** may be about equal to that of each of the conduits **13**, **16**, **17** and **21** but it is preferred that the nozzles **29** be constricted slightly at least so that the air or gas streams issuing from the nozzles are accelerated and able to raise a substantial amount of powder **31** resting in channel **30** into the air stream and create a powder cloud. Such powder as falls back into the channel drifts around in a clockwise direction and soon comes under the stream of the next succeeding nozzle around the channel. The nozzles are spaced closely enough so that the powder drift from one nozzle is brought under the next one and hence no chance is provided for drifts of powder to form and lie dormant.

Within generator wall **22** there is provided a vertical cylindrical bin wall **32** which is open at the top and bottom. The lower edge of wall **32** is slightly spaced above the wall of cone **27** so that powder can slide down the cone into the channel **30**, and the upper edge of wall **32** is preferably at or slightly below the level of the lower end of conduit **13** which extends down a short distance below top wall **23** of the generator. Wall **32** is spaced from wall **22** sufficiently to make the cross section of the annular space **33** greater than that of any of conduits **13**, **16**, **17** and **21** and preferably twice as great or more. Nozzles **29** are located in this annular space and as the powder cloud is generated it rises in this space with a clockwise swirling motion.

Heavy powder particles and agglomerates fall back into the channel partly because of some centrifugal separation which takes place and partly because of the fact that the cross section of space **33** is larger than the conduits and hence the slower speed of the rising air stream is insufficient to support heavier particles. Only the desirable finer particles are carried by the air stream up over the top of wall **32** and out through conduit **13**. Any further agglomerates which may form after the stream passes over wall **32** have a further opportunity to settle out of the air stream into the central bin provided by wall **32**.

The generator may be replenished with powder from time to time by removing screw cap **25** and introducing powder into the central bin through tube **24**. The powder used may be any of those commonly used for powder cloud development, such as a pigmented resin powder, carbon or pigment powder or mixture. In some cases a small proportion of larger so-called "carrier particles" may be maintained in the generator. These particles are preferably triboelectrically related to the developer powder **31** in such a manner as to impart electrostatic charges of the desired polarity to the powder particles to enable the powder particles to be attracted to the electrostatic images to be developed on web **15**. Thus, if the images are positively charged the powder is preferably negatively charged, and vice versa. In some cases, however, it may be desirable to develop the images with powder of the same charge polarity to obtain a reversal print as will be described later. The larger and heavier carrier particles, when used, continually fall back into the channel from space **33**, and hence remain in the powder cloud generator and are not carried through the developing head **14**. Examples of some powder-carrier mixtures are described in U.S. Patent 2,618,551 granted November 18, 1952 to Lewis E. Walkup and in U.S. Patent 2,638,416 granted May 12, 1953 to Lewis E. Walkup and Edward N. Wise but for the purposes of the present invention the proportions of carrier are much less, the carrier amounting to only about 5% to 25% by weight. Also slightly smaller carrier particles are preferred, such as particles which pass through 60 mesh and are retained on 100 mesh, or in some cases even including particles between 100 mesh and 200 mesh, so that they may be readily agitated and moved by the high speed air jets issuing from nozzles **29**.

The interior walls of generator **12** and of conduit **13** and development head **14** may be coated, if desired, with films of material having the desired triboelectric properties to impart the correct polarity of charge to the powder particles. In many cases the structural material itself will have the desired effect and no coating will be necessary. Thus many resinous powders become negatively charged by contact or rubbing against many common metals.

Conduit **13**, also return conduit **16** and conduits **17** and **21**, may be partly or entirely formed of flexible material, such as rubber or plastic hose to enable convenient mounting of the developing head **14** in relation to generator **12** and blower **10**. The flexible conduit also helps to isolate vibrations generated by blower **10** from the rest of the system.

Development head **14** is shown in side view in Figure 1 and in section in Figures 2, 3 and 4. The powder cloud rising through conduit **13** first enters a distributor section **34** in which the stream is spread or distributed in a series of steps into a lamina the width of the image area on sheet or web **15** to be developed, and preferably slightly wider than the image area. The distributor is made of a stack of plates **35** tightly clamped together by bolts **36**, **37** and **38** and provided with cut-out apertures which connect with those in adjacent plates to provide a zig-zag path **39** for the powder cloud, as seen most clearly in Figure 2. The path gradually widens as it passes upward as seen from Figures 3 and 4. The lowermost plates **35**, where the powder cloud path is still narrow, may be thicker than those above to preserve a relatively constant cross section for the passage as it follows its zig-zag upward course. The average cross section of the passage in distributor **34** may be substantially equal to the cross-section of the passage in conduit **13** or it may be slightly less in order to accelerate the stream slightly and reduce the possibility of clogging in the distributor section.

The shape of the passage **39** may be further understood by reference to Figure 4 which is a section taken horizontally through the lowermost cut-out plate **135** looking upward as indicated on the section line in Figure 2.

The passage **39** starts at the outlet of conduit **13** and flares outward at a uniform rate until it reaches an arcuate aperture **40** in adjacent plate **235** after which it reverses its direction but continues in a flaring path cut in plate **335** as indicated by the dashed lines **41** until it reaches an elongated aperture **42** in the next plate **435**, after which

it again reverses direction and so forth. Apertures 40 and 42 are shaped to contribute to the uniform distribution of the powder cloud stream across the width of the path. Thus, aperture 40 comprises an arc having its center at the intersection of the extension of the lines of the sides of the passage cut in plate 135. Aperture 42 may also have an outward curvature centered at the intersection of the lines of sides 41 of the passage in plate 335, or it may have a lesser curvature or be straight. This and subsequent apertures may also be varied in width along their length to aid the spreading of the powder cloud. Thus, they may be constricted slightly in the middle, as shown for aperture 42, to deflect the stream outward toward the ends of the slot. After the stream has passed through the first two or three apertures, such as 40 and 42 it will have reached the full width of the image area but it is desirable to convey the stream through two or more further reversals in its zig-zag path to permit further equalization to take place in the speed and density of the powder stream across its width. The walls of the passage in distributor 34 also contribute to the breaking up of powder agglomerates due to turbulent regions, and to the charging of the powder particles due to contact with the walls of the passage. Plates 35 may preferably be made of conductive material, such as aluminum or other metal. Insulating films, if present, are preferably of negligible thickness to prevent the building up of high electric charges on the inside walls. In some cases, however, the walls may be treated with thin insulating coatings of the desired triboelectric properties to impart charges to the powder, or with conductive coating for the same purpose.

The flattened powder cloud stream passes from the top of distributor 34 to a by-pass valve chamber 43 (Figure 2) where the stream is divided into two flat streams consisting of a developing stream, which passes upward in a flat passage 47 between vertical walls 48, and a by-pass stream which flows through a passage 49 toward the right, as viewed in Figure 2, and joins the returning spent developing stream 50 returning from the image developing zone. An adjustable control valve 44 comprising a wedge-shaped vane on a circular shaft 45 is located in valve chamber 43. The shaft can be rotated a few degrees by manual control handle 46 (Figure 3) to bring valve vane 44 against either of the flaring walls of chamber 43 to divert the stream entirely to either passage 47 or 49 or the vane may be set at any position between these limits to divert a greater or lesser proportion of the powder cloud stream into by-pass passage 49.

The slope of wall 91 which co-operates with vane 44 to form the entrance to by-pass passage 49 is substantially parallel to the direction of the powder cloud stream as it enters valve chamber 43 while the development passage 47 turns upward within the valve chamber. Heavier particles and agglomerates, which may be present in the stream at this point are carried by their inertia into by-pass passage 49 whereas the smaller and lighter particles, which are most desirable for development, are readily carried along with the air stream and are divided between the two passages substantially in the same proportion as the air itself is divided. This provides a developing stream containing mainly or exclusively the finer developer particles, while the larger particles and agglomerates are by-passed to the return passage.

Developer passage 47 extends vertically to its outlet 51 which comprises a horizontal slot from which the developing stream of the powder cloud emerges in an upward direction. A cylindrical development electrode 52 having integral web guide flanges 53 at its ends is mounted for rotation on a shaft 54 supported in bearings in end walls 55 of development head 14.

The axis of shaft 54 and cylinder 52 is parallel to the outlet slot 51 for the powder cloud and is to the right and slightly above the slot outlet, as viewed in Figure 2.

Walls 48 of the developer passage 47 are tapered or curved inward near the outlet and the outlet slot is positioned close to the surface of cylinder 52 so that the powder cloud is ejected tangent to the cylinder surface and substantially in contact with it.

A web guide roller 56 mounted on free-turning shaft 57 has its axis parallel to cylinder 52 in the same horizontal plane and the surface of roller 56 is substantially tangent with the flanges 53 at the left side of the cylinder as seen in Figure 2.

Web. 15, carrying an electrostatic image to be developed, passes down around roller 56 and up between the roller and flanges 53, then around the top of cylinder 52 resting on flanges 53 so that the image area of the web is spaced from the surface of cylinder 52 providing a developing space 58 of approximately the same thickness as that of passage 47 which conveys the powder cloud to the developing space. For greatest effectiveness the developing space is made as thin as possible to bring development electrode 52 as close as possible to the sheet surface to be developed while still permitting passage of the powder cloud between the surfaces. In most cases the spacing is between 5 and 100 mils, which means that flanges 53 will have a diameter of 0.01 to 0.2 inch greater than the diameter of cylinder 52. Roller 56 may be formed of slightly yielding material such as rubber to permit web 15 to be wedged between the roller and flanges 53 at the point of contact or a rigid roller can be used and shaft 57 be mounted on a yielding bearing support.

The electrostatic image on web 15 is located on the surface which faces the development space 58. The web may comprise a flexible electrophotographic plate such as is described, for example, in aforementioned Patents 2,297,691 and 2,551,582. The electrostatic images, of course, are produced by electrophotographic techniques prior to entering the development apparatus. The web may also comprise a conductive foil carrying an electrically charged insulating image, as described, for example, in connection with Figure 11 in aforementioned patent 2,357,809. In other instances the web may consist of insulating sheet material, such as cellulose acetate, polystyrene, polyethylene or other plastic sheeting, or thoroughly dry paper with or without a plastic coating, on which an electrostatic image has been formed as disclosed in aforementioned Patent 2,221,776 or to which an electrostatic image has been transferred or applied by other methods.

As the powder cloud passes around developing space 58 between the surface of cylinder 52 and the image-carrying face of web 15 the powder is attracted to the electrostatic image and is deposited upon the web to form a powder image. Due to the presence of closely-spaced conductive cylinder 52 the lines of force extending from the electrostatic image are largely aligned normal to the image surface and the electric field is concentrated in the developing space where it is effective to attract powder.

In some instances further control of development can be imposed by applying a suitable potential to a curved electrode 59 which follows the curvature of the web as it passes around the development space. Electrode 59 is spaced close to the back of the web and is connected through commutator 65 to the sliding contact 63 of a potentiometer 60. For the present we shall consider the commutator 65 as stationary so that electrode 59 is permanently connected to contact 63. The resistance element of potentiometer 60 is grounded at its midpoint and cylinder 52 is also connected to ground. The ends of the resistance element are connected to the terminals of a battery 61 of several hundred volts potential. By adjusting the position of contact 63 on the resistance element, an electric field is applied between electrode 59 and cylinder 52, and its strength and polarity are readily controlled by the operator.

In most instances a triboelectric charge is applied to

the powder cloud during its generation which is opposite in polarity to the charge of the electrostatic image so that the powder is readily attracted to the image without the aid of an externally applied field. However, frequently the web may carry a small charge in the background areas which will give rise to undesirable background powder in the developed image. By applying a small field from electrode 59 to cylinder 52 which opposes the field of the "background" charge the resultant field in background areas is cancelled or even reversed in direction so that powder is not attracted to these areas. Powder is still deposited in the image areas, however, as these carry higher charges and their field is reduced only slightly by the superimposed field.

In cases where the electrostatic image is weak the potentiometer can be adjusted to provide a field aiding the image field. This results in some background powder but it produces a heavier deposit on the image areas which is often helpful in making a weak image more legible.

Reversal development may also be effected by use of electrode 59. A powder cloud is produced having the same polarity of triboelectric charge as the image areas. Hence the powder is repelled from the image. When a field is applied by electrode 59 which opposes the image field powder is attracted to the uncharged "background" areas to develop a reversal print.

The quality and character of continuous tone images can also be controlled by placing potentials on electrode 59. It is often desirable to vary the maximum and minimum density of a print, to control the contrast, and in some cases to accentuate development of areas having a given charge density. To increase the brightness of highlights contact 63 may be set to a point which will apply a field which cancels the field from the highlight areas. To increase the overall density a field may be applied to aid the deposition of powder over the entire web area.

To emphasize the darker areas a different technique may be employed, involving the use of commutator 65. The commutator has a rotary contact 66 connected to electrode 59 and normally at rest on a stationary commutator segment 67 which is connected to potentiometer contact 63. The commutator is provided with a series of short contact segments similar to 67 and rotary contact 66 can be driven by motor 68, when energized, to sweep across the stationary contacts. Potentiometer contacts 62 and 64 are connected to other segments and movable conductive bridging pieces 69 are used to connect adjacent segments where required to produce larger segments connected to any of the potentiometer contacts. By setting the positions of contacts 62, 63 and 64 and placing bridges 69 to connect the segments together in groups it will be apparent that the potential of electrode 59 is cycled through a series of values as contact 66 is rotated and that the percentage of time at any potential is determined by the number of segments joined to a given potentiometer contact by the bridges 69.

To emphasize the darker areas of the image a potential is applied to electrode 59, for say 50% of the time, which is opposite in polarity to the image and sufficient to produce a field strength which will cancel or reverse the field from all except the most highly charged image areas. During this period of each cycle of commutator 65 only the highly charged areas are developed. For another period, say 40% of the cycle, the potential is lowered to permit some development of intermediate tones along with further development of dark areas and finally, for the last 10% of the cycle the potential may be lowered still further to allow a slight fill-in in the lighter areas. The commutator may complete a cycle in one second or less and pass through several cycles during the travel of a given point of the web through the development zone. Other forms of development can also be achieved with the cycling system, including reversal development.

Electrode 59 is most suitably used with webs 15 consisting entirely of insulating material. Where a conductive backing is provided on the web electrode 59 may be brought into direct sliding contact with the backing to apply its potential directly to the conductive backing. Where this is not feasible cylinder 52 may be electrically insulated from the head 14 and various potentials applied to it while the conductive web backing is held at ground potential, or if no conductive backing is present electrode 59 may be used at ground potential.

The web 15 is drawn out of developing head 14 and downward and outward to the right (Figure 2) by a pair of co-acting rubber rollers 70, 71 driven at the desired developing speed. In place of rollers 70, 71 the web may be wound up on a motor-driven take-up reel. In event the powder image is to be transferred to another surface the web may be carried through a transfer mechanism where a web of sheet transfer material is brought against it, or in some instances transfer can be effected by feeding a sheet or web of adhesive-coated material between roller 71 and web 15. Between head 14 and rollers 70, 71 the web passes through a fuser 72 which may be energized when it is desired to affix the powder images directly to web 15. The fuser may comprise an electric oven having entrance and exit slots for the web, or it may be a chamber containing the vapor of a solvent for the powder image or for a plastic coating on the web.

As web 15 is drawn away from flanges 53 it passes over the edge of enclosing wall 73 of head 14 and is spaced slightly from it in the image area to avoid contact with the powder image. The spent powder cloud continues down around cylinder 52 and then straight down through return passage 50 where it joins the by-pass stream from passage 49 and the combined stream returns to the blower 10 through conduit 16. Distributor plates 35 are provided with aligned apertures 74 (Figures 2 and 4) of decreasing length from top to bottom to converge the return stream into circular conduit 16.

While cylinder 52 may be rotated by the drag of the web as it passes around flanges 53, it is often desirable to provide a positive drive for the cylinder to enable accurate control of the web speed in the development zone and to avoid imposing a drag on other parts of the equipment. As seen in Figure 3, shaft 54 on which cylinder 52 is mounted, can be driven by motor 75 through speed reducer 76, which may include a one-way clutch 92 to enable the web to be pulled forward independently of motor 75 when the motor is not needed, and also during initial threading of the web.

As previously stated one of the principal drawbacks of development electrodes in the past has been the need for frequent shutdowns for cleaning. The development electrode cylinder 52 here provided is cleaned during each cycle of rotation. A thin blade 77 is supported on frame member 78 to slide lightly against the surface of cylinder 52 where it descends away from the developing space. Any large accumulations of powder are scraped lightly from the cylinder and fall into the returning spent powder cloud stream. Any thin powder deposit still remaining on the cylinder is then brushed off the cylinder by a brush 79 supported on spring arms 80 inside a chamber 81 below the cylinder. A clean-out hole 82 is provided in the end wall of the head at the bottom of chamber 81 for occasional removal of accumulated powder.

Blade 77 may be formed of thin steel or Phosphor bronze shim stock. Brush 79 may be a fine bristle brush, plush, or a soft felt pad.

By virtue of the expulsion of a small amount of air through filter 18 there is a slight suction produced at the places where web 15 enters and leaves developing head 14 so that a slight intake of air is produced and loss of powder cloud is prevented or minimized.

Figures 5 and 6 illustrate a modification of the development head to provide a more positive support for web

15 and independent rotation of the development electrode. Web 15 passes around the development zone on a pair of rollers 83 which are free to rotate on shaft 84 of developing electrode cylinder 85. A pair of endless rubber or fabric belts 86 pass around guide pulleys 87 then down around pulleys 88 and up between pulleys 88 and rollers 83 where web 15 is brought against the rollers. The belts then pass around the rollers 83 resting on the edges of web 15 and securely holding it against the rollers. The belts then pass around rollers 89 at the point where web 15 leaves rollers 83 and the belts return over pulleys 87 to complete their cycle. The web may be advanced at any desired speed by take-up rollers 70, 71 (Figure 1) independently of the motion of cylinder 85. Cylinder 85 is driven by gear 90 on shaft 84 from a motor and speed reducer drive, as previously described. This makes it possible to adjust the web speed and electrode speed independently for most efficient operation.

A powder cloud development mechanism has been described which provides for efficient and continuous generation of a powder cloud, triboelectric charging of the particles thereof to a desired polarity by contact with carrier particles or with the walls of the generator, or both, separation of large particles and agglomerates, and breaking up of agglomerates by turbulence. The system also provides for spreading of the powder cloud into a uniform lamina the width of the area to be developed, the controlled by-passing of any proportion of the powder cloud to vary the intensity of the developing stream and also to remove further large particles and agglomerates from the developing stream, and the return of spent developer and by-passed material to the powder cloud generator.

Provision is also made for control of development by a conductive development electrode and by potentials applied to said electrode or to a control electrode spaced from the development electrode. The mechanism provides for continuous development of web or sheet material and for continuous cleaning of the development electrode.

Means are also provided to maintain a net suction on the development mechanism to prevent escape of powder cloud out of the system.

Other features include independent control of web speed and speed of cycling of the development electrode. Further features are apparent in the preceding specification and in the appended drawings.

It is apparent from the principles set forth in this invention that certain modifications can be made without departing from the spirit of the invention. For example, it is contemplated that cloud return passage 50 in the developing head can be provided with a zig-zag path similar to entering passage 39 to converge the stream uniformly into return conduit 16.

Although the system has been described as an air system it is apparent that other gases can be circulated and where the word air is used in the claims, gases in general are intended.

While the present invention, as to its objects and advantages, has been described herein as carried out in specific embodiments thereof, it is not desired to be limited thereby but it is intended to cover the invention broadly within the spirit and scope of the appended claims.

What is claimed is:

1. A powder cloud generator comprising a vertical cylindrical chamber, a source of air pressure, a plurality of nozzles fed thereby located at angularly-spaced intervals around the inside of said cylinder and directed circumferentially to create a swirling air flow within the base of a said cylinder, means for introducing powder into said cylinder, and a powder cloud outlet near the top of said cylinder.

2. A powder cloud generator as claimed in claim 1 in which a powder bin is provided having a discharge opening within said cylinder near its base whereby powder is discharged from said opening into said cylinder when the level of powder falls below said opening.

3. A powder cloud generator comprising a vertical cylindrical open-ended member positioned concentrically within a cylindrical chamber enclosed at the top and bottom, said cylindrical open-ended member being spaced apart at its top and bottom from said chamber, means to create a swirling flow of gas around said open-ended member and between said open-ended member and cylindrical chamber, and output means at the top of said cylindrical chamber adapted to feed out of said chamber a mixture of powder particles in gas.

4. Apparatus according to claim 3 including means to feed powder from within said open-ended member into the path of the swirling flow of gas around said open-ended member and between said member and said chamber.

5. A powder cloud generator comprising a vertical cylindrical chamber enclosed at the top and bottom, a plurality of tubes positioned and disposed within said chamber each terminating in a constricted nozzle, each of said nozzles being positioned downwardly slanting in said chamber and in the same rotational sense and near the wall of said cylindrical chamber, means to feed gas under pressure to said tubes in said chamber and through said tubes to and through said nozzles to create a swirling air flow within said chamber, and output means from said cylindrical chamber.

6. A powder cloud generator separator combination comprising means to generate a powder cloud including a gas supply, a powder supply and means to feed said gas supply to said powder supply, means to subject a generated powder cloud to centrifugal action, means to feed a mixture of fine particles in gas to an output zone while substantially excluding coarse particles from said zone, and means to withdraw from said output zone a mixture of fine powder particles in gas for xerographic powder cloud development.

7. A powder cloud generator comprising a vertical cylindrical chamber enclosed at the top and bottom, means to feed gas under pressure into said chamber, an inverted cone positioned in said chamber and at the base thereof with its apex at about the axis of said cylindrical chamber, a plurality of tubes positioned and disposed near the apex of said cone and extending outward substantially horizontally and substantially radially within said chamber, a constricted nozzle positioned at the end of each tube positioned downwardly slanting and angularly to said tubes, said nozzles all pointing in the same rotational sense, means to feed the input gas to said chamber to said tubes and through said tubes to said nozzles, and output means from said cylindrical chamber, the path of gas fed into said chamber including passage through said tubes and then through said nozzles and into the channel formed between said inverted cone and the walls of said cylindrical chamber to create a swirling flow of powder positioned within said chamber and then out said output means.

8. A powder cloud generator comprising a vertical cylindrical chamber enclosed at the top and bottom, means to feed gas under pressure into said chamber, an inverted cone positioned in said chamber and at the base thereof with its apex at about the axis of said cylindrical chamber, said cone having walls extending outward to the walls of said chamber, means for introducing powder into said cylinder and to the channel formed between said inverted cone and the walls of said chamber, a plurality of tubes positioned and disposed near the apex of said cone and extending outward substantially horizontally and substantially radially within said chamber, a constricted nozzle positioned at the end of each tube positioned downwardly slanting and angularly to said tubes, said nozzles all pointing in the same rotational direction,

means to feed the input gas to said chamber to said tubes and through said tubes to said nozzles, and output means from said cylindrical chamber, the path of gas fed to said chamber including passage through said tubes and then through said nozzles and into the channel formed between said inverted cone and the walls of said cylindrical chamber to create a swirling flow of powder positioned within said chamber and then out said output means.

9. Apparatus according to claim 8 in which the walls of said cone are at an angle with the cylinder axis of about 45° or less.

10. Apparatus according to claim 8 including a vertical cylindrical open-ended member positioned concentrically within said cylindrical chamber spaced apart from the

wall of said cone and spaced apart from the upper end of said cylindrical chamber and creating an annular spacing between said cylindrical chamber and said cylindrical member, said constricted nozzles being positioned within said annular spacing.

11. Apparatus according to claim 10 in which said cylindrical member is positioned and disposed in relation to said cylindrical chamber to form in the annular spacing a cross sectional area at least about twice as great as the cross sectional area of the output means.

References Cited in the file of this patent

UNITED STATES PATENTS

2,812,883 Hayford ..... Nov. 12, 1957