

Dec. 3, 1957

P. G. ANDRUS ET AL

2,815,330

GENERATOR OF AEROSOL OF POWDER IN GAS

Original Filed March 14, 1955

2 Sheets-Sheet 1

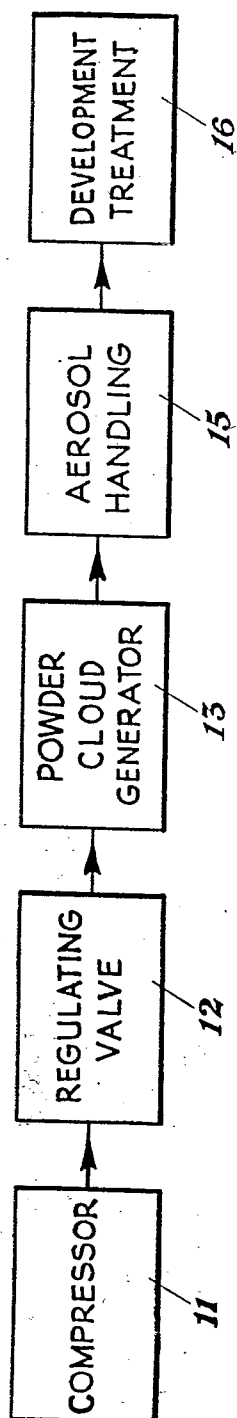


Fig. 1

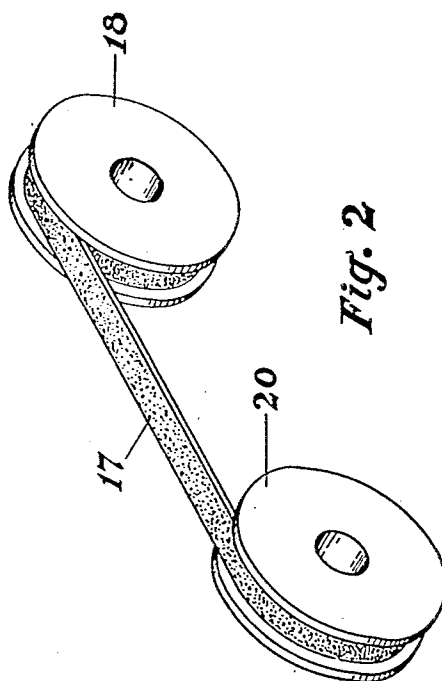


Fig. 2

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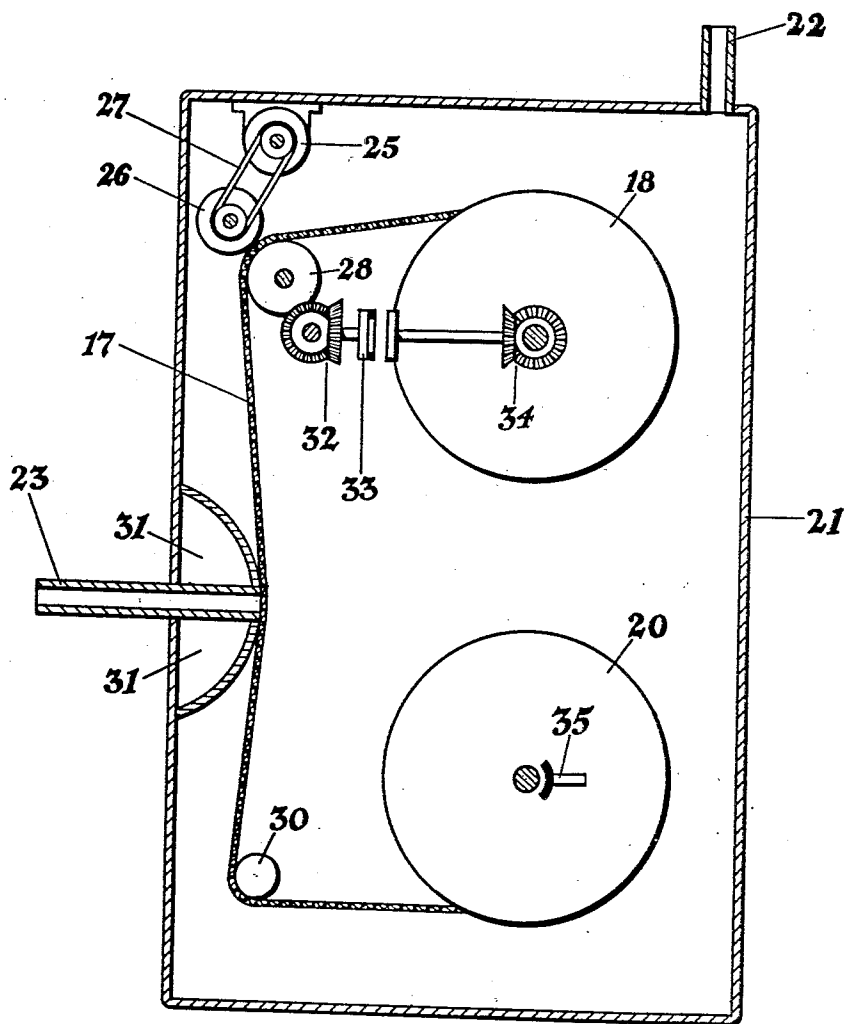


Fig. 3

1

2,815,330

GENERATOR OF AEROSOL OF POWDER IN GAS

Paul G. Andrus, Columbus, Earnest Paul Matthews, Alliance, and Eugene C. Ricker, Columbus, Ohio, assignors, by mesne assignments, to The Haloid Company, Rochester, N. Y., a corporation of New York

Original application March 14, 1955, Serial No. 511,363. Divided and this application April 29, 1955, Serial No. 504,726

3 Claims. (Cl. 252—359)

This invention relates in general to xerography and in particular to the development of electrostatic charge patterns. This is a division of our copending patent application having a U. S. Serial No. 511,363, entitled, Belt Powder Cloud Generation, filed March 14, 1955.

Xerography uses the physical phenomena of photoconductivity and electrostatic attraction of electrostatically charged bodies to convert a light image into a physical image consisting of, for instance, black powder on white paper. The xerographic plate consists of a film of a photoconductive insulating material on a metal backing plate. In use, the plate is given an electrostatic surface charge and then exposed to a light image, which results in an electrostatic image on the plate surface. This electrostatic image, which may be allowed to remain on the plate or which may be transferred, is developed by allowing it to attract and collect electrically charged particles of powder. The powder image may then be transferred and fixed to another surface, usually a sheet of paper, and the plate may be cleaned for reuse or the powder image may be allowed to remain on the plate for photographing, viewing, or the like.

The xerographic plate usually consists of a sheet of metal on which a film of selenium has been deposited uniformly by a vacuum evaporation process. Materials other than selenium may be used; sulfur and anthracene are examples, though both are much slower photographically than selenium. A material suitable for the film on a xerographic plate must be a good enough insulator in darkness to retain an electrical charge on its surface for sufficient time to permit exposure and development of the plate before much of the charge has leaked away. The material also must dissipate its charge rapidly when the plate is exposed to light.

When sensitizing the plate, ions are deposited on the surface of the plate by the action of an electric field. Two arrangements have been found practical for sensitizing plates: (1) corona discharge to provide both the ions and the electric field, and (2) a radioactive alpha particle source to ionize the air, used in conjunction with an electrical field to move ions to the plate.

The xerographic plate, once sensitized, may be exposed in any of the ways ordinarily used for exposing silver halide photographic materials. After exposure to a light image, the plate bears an electrical image in which the most highly charged areas correspond to the areas of least illumination in the light image, the areas of least charge correspond to areas of greatest illumination in the light image, and those of intermediate charge correspond to areas of intermediate illumination. This electrical image is developed by bringing into contact with it powder particles.

Two methods of image development are in use. One is described in Walkup U. S. Patent 2,618,551 and is known as cascade development. In this technique, the powder is mixed with a granular material and this two component "developer" is poured or cascaded over the plate surface. The other form of development is known

2

as powder cloud development, and is described for example in Carlson U. S. Patent 2,221,776. In this technique of development, a dispersion of powder particles in gas is passed to the surface area bearing the electrical image and properly charged particles are drawn out of the cloud to form a powder deposition in electrical image configuration.

The powder image on a plate or other surface may be conveniently transferred electrostatically to paper by placing the paper on the powder image and applying a high potential to the back of the paper. Another technique for the transfer of the image from the plate surface is by transferring the powder image to an adhesive coated material, such as paper or the like.

The powder image may be fixed to the transfer material in one of several ways. Some xerographic powders are composed of a resinous material pigmented with carbon black. These powders may be fixed by heat fusing or by exposing to solvent vapors. Other powders such as finely divided charcoal used in some forms of xerography are fixed by spraying with a fixative or by covering them with a transparent adhesive coated film.

It is an object of this invention to improve upon means and methods for the development of electrostatic latent images.

It is also an object of this invention to improve upon apparatus for the development of electrostatic latent images.

It is a further object of this invention to improve the art of xerography by improving powder cloud generators for powder cloud development.

It is a still further object of this invention to provide new means and methods for creating aerosols of powder in gas.

Generally in powder cloud creating apparatus there is included a powder source, means to create a cloud of powder in gas, means to convey the cloud to a surface carrying an electrostatic latent image, and means to treat powder in the cloud before it reaches the plate. Such devices, which include one or a number of the above elements, and which are used to take powder from a source, whether it be a mound of powder or whether it be in other shapes or forms, and convert the powder to an aerosol of powder in gas is herein, and generally in the art, referred to as a "powder cloud generator" or as a "cloud generator."

An object in the art of xerography, as in any art concerned with image reproduction, is that of uniformly developing high quality copy. Means of obtaining this objective while using powder cloud development is through the uniform and constant presentation to the electrostatic latent image on a surface of a powder cloud of fine developer powder particles uniformly and densely dispersed throughout.

And, it is another object of this invention to improve upon powder cloud generators so that a more uniform and more dense dispersion of powder particles in gas than has heretofore been possible is created.

It is yet another object of this invention to improve upon means and methods of creating uniform and dense dispersions of particles of powder in gas.

The invention of this application follows a new theory for generating uniform and dense powder clouds. According to this theory, a tape or belt of cloth or the like which has been uniformly loaded with powder particles is passed over an output tube at a uniform rate. Particles are blown from the belt or tape in a controlled air stream, thereby producing a controlled aerosol of uniformly constant and dense dispersions of powder particles.

For a better understanding of this invention, together with other further objects thereof, reference is now had to the following description taken in connection with the

accompanying drawings, and the scope of the invention will be pointed out in the appended claims.

Fig. 1 is a block diagram of elements which generally appear in xerographic cloud creating apparatus for use in developing electrostatic charge patterns.

Fig. 2 is an isometric drawing of an embodiment of a belt which may be used in powder cloud generator according to this invention.

Fig. 3 is a cross section view of an embodiment of a powder cloud generator according to this invention.

Referring now with more particularity to the drawings, in Fig. 1 is shown a block diagram of elements which compose cloud creating apparatus for development of electrostatic latent images. As is indicated in this diagram, compressed air is fed from compressor 11 to a powder cloud generator 13 through a regulating valve 12, and the output of the powder cloud generator is fed through an aerosol handling block 15 and then to the development zone 16 whereat electrostatically charged developer particles are passed for development purposes to a surface carrying an electrostatic latent image.

The source of compressed air or pressurized gas may be any suitable source, such as for example, an air pump or like pressure generating member or a suitable pressurized gas container. Such containers are readily available on the commercial market in the form of gas capsules of carbon dioxide or the like under pressure, in the form of bombs or the like of gas such as fluoro-chloro-alkanes, which are available under the general family name of Freon. Similarly, a suitable system may comprise a pump or generating means optionally in combination with a pressure chamber whereby fluctuations in pressure may be limited or avoided.

Regulating valve 12 is used to control the rate of flow of gas from compressor 11 to powder cloud generator 13 and also to control the pressure of gas supplied to the powder cloud generator. The powder cloud generator, which is the next block in this diagram following regulating valve 12, is used to create an aerosol of powder particles. It may be supplied with powder in what may be termed the raw or bulk form, that is powder taken directly from a container and directly supplied in that form without treatment to a powder cloud generator, or it may be supplied with powder which is first treated or positioned and then placed in the generator. The particular powder used is dependent on a number of factors such as other elements used in the cloud creating apparatus, the form of xerographic development, the desired quality of final copy, and the like. A more detailed discussion of powders will appear below.

The aerosol handling block 15 of the diagram appearing in Fig. 1 may represent any number of means and apparatus for imparting an electrostatic charge to the individual powder particles in the aerosol supplied from the powder cloud generator or it may represent any number of means and apparatus for deagglomerating particles fed in the aerosol from the generator. Charging and deagglomeration of particles may be accomplished by turbulently flowing them through fine capillary tubes. Charging may also be accomplished by passing the aerosol of powder particles through a corona discharge zone, or the like.

The aerosol is next supplied, as indicated by the block diagram, to development zone 16. Generally, this zone includes a means for expanding the aerosol, and optionally this may be done by leading the air from tubes or the like to a larger area where the aerosol expands, creating the cloud or expanded aerosol of developer particles in gas. It is also feasible and sometimes desirable to use the particles in aerosol form without expansion.

In xerography in order to develop a true copy of the original image, it is generally desirable to develop by depositing particles in opposition to gravitational pull in that the electrostatic charges on the image bearing surface truly represent the pattern of the image projected to the

plate surface, and deposition of particles in opposition to gravitational forces prevents production of a distorted reproduction. This may be accomplished by positioning the plate with the image bearing surface facing downward and creating a cloud beneath it. Particles which deposit because of other forces may be removed during the development process through the use of such techniques as directing slight air currents or winds to the plate surface. Such winds or currents should be sufficient to remove particles not held in place due to electrostatic forces, but should be limited so that particles electrostatically held in place are not affected.

It is to be understood that many modifications may be made in the apparatus described in connection with the block diagram shown in Fig. 1.

For example, a device may be inserted between the powder cloud generator and the aerosol treating block for purposes of further deagglomerating clumps of particles fed in the aerosol fed from the powder cloud generator. A device may also be inserted between the powder cloud generator and the aerosol treating block for purposes of dehumidifying the developer powder particles. Such a device may also be inserted between the aerosol treating block and the development zone block. These modifications have been included herein for purposes of demonstrating that the powder cloud creating device shown and described in connection with Figure 1 is for illustrative purposes and is intended to include within its scope modifications and equivalents able to accomplish the purpose of generating a powder cloud for deposition on electric charge patterns.

Reference is now had to Fig. 2 wherein is shown a detailed drawing of an embodiment of a belt or tape which may be used in powder cloud generators according to this invention. As appears in this figure, the belt or tape 17 stretches between two spools, spool 18 and spool 20. The belt 17 may be loaded or impregnated with xerographic developer powder particles across its entire width or it may be impregnated or loaded with developer powder particles only across a portion of its width. Belts may be impregnated by brushing the powder by hand into or against the belt and belts may be impregnated or loaded by tumbling powder over the belt material and scraping off excess powder with a blade or the like. Another technique for loading a belt is that of working the powder into the material using a spatula or pressing the powder into the material between two surfaces. In the brushing technique, the material is placed on a solid support and large quantities of powder are brushed over the material in all directions with a soft bristled brush. Excess powder is removed by shaking the belt. These manual techniques for impregnating belts are entirely satisfactory for some uses. However, for high quality xerographic development, it is desirable to eliminate the variables and human elements of error which are present with these manual techniques. This may be accomplished by using an automatic loading machine in which a uniform aerosol of powder particles is directed at the belt material as the belt or tape moves at a uniform rate of speed through the aerosol. The aerosol of powder particles which is directed at the belt material should travel at a low enough velocity so that most of the powder particles in the aerosol deposit on or in the belt material. Also the movement of the gas of the aerosol traveling through the belt should not act to remove the particles in or on the belt material.

Another important consideration in forming belts for high quality xerographic reproductions is the belt material itself. The material should be uniform throughout. This will assure presentation to the aerosol of a material which is at all points able to hold the same amount of particles and also a material which presents the same resistance to the flow of particles in the aerosol. The belt material may be any porous material such as cotton, asbestos, wool, velvet, silk, synthetic materials, fibrous

materials, and the like. A particularly valuable asset of the material used for belt or tape 17 is that of its having a high nap. Medium weight cotton flannel, for example, has been found to work exceptionally well as a belt 17. Equivalents of cotton flannel, such as cotton tape or bias tape material, have been prepared by rubbing the tapes with a wire brush to bring up a nap or to create a uniform roughness on the tape or bias surface, and such equivalents have been found to work equally as well.

In impregnating or loading belts, it has been found that belt materials will accept powder to a saturation point. Powder carried to the belt material above the saturation point may be shaken loose to further assure uniformity in belt loading through belt loading of all areas to the saturation point. It is to be realized, of course, that belts may be loaded well below the saturation point by passing a tape or belt through an aerosol at high enough speeds to avoid loading to the saturation point or by using a thin aerosol in impregnating the belt material. Using an automatic loading machine, it is possible to saturate the belt material with powder particles by passing the belt through the aerosol one time or a number of times. More load per belt will naturally result using the same aerosol when the belt is passed through it at the same rate of speed a greater number of times. However, when belt saturation is reached, powder particles will no longer form as a part of belt material, and although some particles may deposit on areas of the belt, these particles may be removed by shaking the belt or the like.

It is to be realized that belts are used as an integral part of this invention. However, it is not intended in this invention to devise new means, methods or apparatus for loading or impregnating belts or tapes for use with this invention. The above techniques and apparatus have been suggested for illustrative purposes as means of attaining a belt uniformly loaded or impregnated with xerographic developer powder particles, and the use of all such belts whether the particular technique for making them has been disclosed herein or not, is intended to be encompassed by this invention.

Reference is now had to Fig. 3 wherein is shown a simple embodiment of a powder cloud generator according to this invention. As in Fig. 2, the belt is designated 17 and the spools are designated 18 and 20. A housing 21 encloses the elements of the powder cloud generator and has projected through it an input tube 22 and an output tube 23. A motor 25 acts on and drives a drive capstan 26 through a drive-belt 27. It is to be realized, of course, that motor 25 may be positioned externally of housing 21 and the drive-belt 27 extending from motor 25 to drive capstan 26 can extend to an extension or the like of capstan 26 projecting out of housing 21. It is also to be understood that there is no intention to limit the apparatus of this invention to a particular driving mechanism, but instead other means of driving or causing uniform movement of belt 17 generally known to those in the art are intended to be encompassed by this invention.

Drive wheel 28 is positioned to cause belt 17 to contact drive capstan 26. The top surface of drive capstan 26 in this embodiment is roughened and provides a friction form of drive to belt 17, thereby imparting motion to the belt. Drive wheel 28 is caused to rotate by the movement of belt 17 in contact with its surface. Driving forces of rotating drive wheel 28 are supplied through gears 32, through friction clutch 33 and through gears 34 to the take-up spool, herein designated spool 18. It should be realized that the gearing mechanism and friction clutch could be directed to spool 20 and that this mechanism has been connected to spool 18 in this embodiment only for illustrative purposes. The use of the friction clutch and the gearing mechanism to drive the take-up spool is to cause the take-up spool to wind up as much belt material as is supplied to it following use of

belt 17 in creating the powder aerosol. The speed of rotation of the take-up spool will vary, depending on the amount of belt material already wound up on the spool, and this variance is provided for through the friction clutch mechanism. Other mechanisms to accomplish the same purpose are intended to be encompassed by this invention. The freedom of rotation of the supply spool is controlled by a friction brake 35 or like mechanism. Control on the supply spool in this way aids in keeping tension on belt 17 as it moves through its path from the supply spool to the take-up spool.

Drive wheel 28 is also positioned to cooperate with guide rod 30 to cause positioning of belt 17 during its travel from the supply spool to the take-up spool over and in contact with the internal opening of output tube 23. Fitting 31 surrounds this opening and is formed to present a smooth and uniform surface to belt 17 to allow uniform and smooth movement of belt 17 over the internal opening of output tube 23. The internal opening of output tube 23 should extend to a point within housing 21 which distorts the normal straight line movement of belt 17 between guide rod 30 and drive wheel 28 to assure close contact of belt 17 with the internal opening of output tube 23. Guide rod 30, it is to be realized, may be a rod, blade, roller or the like.

The belt generator shown in Fig. 3 is prepared for operation by loading it with a loaded belt similar to the belt shown in Fig. 2. The loaded belt is generally all on one spool, as for example, spool 20, but it is to be realized, of course, that it could extend between two spools. Spool 18 should be an empty spool when the entire belt is loaded on spool 20 and should be of such size so that it can accommodate all of belt 17. Belt 17 is threaded from spool 20 to spool 18 by being positioned between guide rod 30 and housing 21 and then over fitting 31 and the internal opening of the output tube 23 and then between drive capstan 26 and drive wheel 28 from where it goes to spool 18. When motor 25 is operating, capstan 26 is caused to rotate, which results in movement of belt 17 at a uniform rate and also results in movement of spool 18 to cause take-up of belt 17 as it is fed between capstan 26 and drive wheel 28.

A regulated supply of gas is supplied through input tube 22 to housing 21 and a mixture of particles in gas is emitted through output tube 23. The powder for the mixture of powder in gas is supplied from belt 17 which passes over the internal opening of output tube 23. Output tube 23 is the only means of escape provided from the housing for the gas fed therein. Belt 17 passes over the internal opening of output tube 23 and presents a barrier through which the escaping gas must pass. In passing through belt 17, the gas carries with it the powder particles which have been and are impregnated into and carried by belt 17. Thus, the aerosol of powder particles is created at the output end of output tube 23.

To assure proper operation of a powder cloud generator according to this invention, it is desirable to use a belt wide enough in width to entirely cover and extend beyond the internal opening of output tube 23 within housing 21. Using such a belt will prevent the escape of gas around the belt material, which would cause inefficient powder particle aerosol creation. Generally, when dense clouds of powder particles are desired, a belt should be used which is loaded over an area wider than the area of the width of belt 17 over which the internal opening of output tube 23 extends. Such a belt further assures uniformity in density of cloud created. All the escaping gas in such an instance passes through loaded areas of the belt only.

The output tube 23 may take varying shapes and forms. Generally the particular shape depends upon the particular output desired and the particular use to be made of the output aerosol. For example, the output tube may be a circular tube or may comprise a number of small tubes positioned to create, in effect, a similar circular out-

line or other outline. It may also take the form of a rectangle, square, or the like. It may also vary throughout its length, as for example, the internal opening may comprise a capillary tube or other tube which feeds into a wider zone and then feeds into a number of individual tubes or the like. Dimensions of an output tube which are herein included only for illustrative purposes and are not intended to limit the invention in any way, comprise a .007 inch by 1/4 inch rectangular slot type of internal opening in a plate fastened over a block containing a 1/4 inch drilled hole leading next into a .046 inch drilled hole. To the .046 inch diameter circular area any of a number of means of conveying an output for use in xerography may be attached. The particular output tube being described has been used generally with belts which are loaded approximately 1/2 inch across their width and a generator using these elements may be used to develop high quality continuous tone xerographic prints in a total time of one second, and in some instances in less time.

Using this generator, it has been found that approximately 4 inches of belt are necessary for the development of a 4 x 5 print. To develop such a print in one second, it is necessary to move the belt at the rate of 4 inches of belt per second over the internal opening of output tube 23. For greater speed in development, a faster linear speed for the belt is necessary, and for longer development time slower linear speeds are used. Generally, although one second developments are obtainable, three second developments have been found to produce slightly higher quality images. For a three second development using the specific elements described above, the free air flow at the output end of output tube 23 is approximately 2.24 cubic feet per minute with a pressure within housing 21 of 60 p. s. i. The belt used to obtain the specific data above was of cotton flannel material. It is to be realized that greater amounts of air flow and lesser amounts of air flow are intended to be encompassed by this invention. The air flows and pressure used in the data supplied above are taken in connection with feeding the output aerosol from the output tube to a capillary tube for further deagglomeration and charging before feeding the particles to a development zone. The use of capillary tubes or the like requires high pressures and relatively high air flows in order to create turbulent flow of the particles through the capillary tube, which acts both to scour the internal walls of the tube and thereby keep the tube clean, and also to electrostatically charge the particles as they pass through the tube to development zone. When tubes larger than capillary tubes are used, lower pressures and lower rates of air flow are sufficient for valuable aerosol outputs for use in development in the art of xerography.

From the point of view of composition of the developer particles impregnated into the tape or belt of material, prints or pictures may be produced with charcoal, carbon blacks, or carbonaceous pigments. Under proper conditions, any of a number of various carbon or lamp black materials may be employed, including such material as furnace blacks, channel blacks and the like. In addition, there may be used such material as milled charcoals and similar materials, or, if desired, finely divided materials having added pigment matter. In the latter category are materials such as finely divided resins containing pigments or dyes such as carbonaceous pigments or various coloring pigments and the like, compositions of this type being preferred where the print or picture ultimately is to be made permanent by a fusing process including heat or vapor fusing. Best prints to date have been made using milled wood charcoal.

A loaded or impregnated belt is presently believed to have powder extending through all areas of thickness of the belt material. The load accepted by each belt is dependent on the density of the cloth and the ability of the cloth to load with powder particles. By ability of the cloth to load it is intended to include such elements as

the effect of the cloth's mesh and the cloth's nap, whereas the density is intended to include the effect of such elements as the thickness of the cloth. Powder loaded or impregnated to the belt deposits both between the threads and on threads and between areas of napped material and on the napped material. Belt materials, it is presently believed, have a saturation point above which they will accept within themselves no more xerographic developer powder particles. Although powder particles may be fed to the belt material and although such particles may occasionally remain resting on the surface, they are easily removed by simply shaking the loaded belt. Thus, particles above the saturation point of the belt will shake loose, whereas those particles below the saturation point which have become part of the belt material will remain adhering to the belt material.

Particular features of this invention bring about very high quality xerographic reproductions. In the first instance, it is desirable to have a uniform belt uniformly loaded with powder particles. Next, it is desirable to pass the belt over the output tube at a highly uniform rate of speed while maintaining a highly uniform flow of air into and through the air-tight housing. When such measures are taken, the powder cloud generator of this invention produces very fine high quality reproductions.

Throughout, much has been said about high quality reproductions, without much definition or explanation of what has been intended. Quality in xerography has the same qualifications as are found in the art of photography. It is desirable to maintain graininess to a point beyond which the human eye cannot see. The average grain size of primary particles using powder cloud generators according to this invention, for example, is believed to be about .3 micron.

The subjective considerations which are present in the art of photography are also present in the art of xerography. That is, the final print must appear pleasing to the eye and must appear true to the eye. These subjective considerations are obtained by reproductions made using the powder cloud generator of this invention.

In addition to the fine photographic qualities desired in prints, there are also xerographic characteristics which should be present. Using powder particles to develop images means that agglomerates of powder particles may form and may deposit when developing the print. A good xerographic development system holds the number of agglomerates to a minimum and also holds the size of the agglomerates to a minimum. The size of agglomerates and the frequency of agglomerates using the powder cloud generator of this invention are low in both instances.

In xerography it is also desirable to have complete development. Complete development in xerography is intended to include avoidance of what has become known as the halo effect and the avoidance of fringing of images. The halo effect is a form of halo around developed areas, and fringing is a form of blurring or extending outward from the true image area of developer particles. The powder cloud generator according to this invention when used in conjunction with the proper development system is capable of very good, complete development. Sensitometric considerations also enter into xerographic reproductions. The desirable features of the powder cloud generator of this invention aid in producing response curves in the xerographic process, which results in good correspondence between the original and the reproduction of the original. The resolution of xerographic prints produced while using powder cloud generators according to this invention can reach at least fifty lines per millimeter, and a brightness acceptance range of 1.6 density steps has been achieved.

A further factor which qualitatively defines the output of powder cloud generators according to this invention is the output consistency either using the same belt or using different belts of equivalent materials and equiv-

alent powder loads. An examination of a large number of prints made with generators according to this invention has been made, and only a slight variance between prints was noticed. Consistency in output throughout the entire belt and from belt to belt is shown by this experiment. Consistency of uniformity of dispersion is also present throughout a belt and from belt to belt.

A further advantage of generators according to this invention is that they are able to deliver a dense cloud which is highly, finely divided, in a very short time. Also, it is to be realized that generators according to this invention may be quite compact if it is found desirable or necessary to place them in small areas. The limit on compactness or smallness is the size of the two spools. Also it is to be realized that when the powder on a spool is used up, replacement of spools may be easily made, as for example, through the loosening of wing nuts or the like, without much time loss in equipment operation.

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

What is claimed is:

1. A generator of an aerosol of powder particles for development of xerographic images comprising a gas tight housing, an input tube, an output tube having an internal opening within the housing and an external opening extending outside said housing, said input tube adapted to supply a flow of gas to said housing from a compressed gas source at a sufficient pressure to form an aerosol of powder particles at the internal opening of the output tube, said output tube adapted to feed an aerosol of powder particles from said housing, a porous tape of material adapted to hold powder particles, releasable to gas flow through said tape, positioned within said hous-

ing, and means within said housing to position a portion of the tape of material over the internal opening of the output tube, said input tube being positioned relative to said output tube to feed compressed gas into said housing and then through the portion of the tape material over the internal opening of the output tube and then out said output tube.

2. A generator according to claim 1 in which the porous tape of material is positioned within said housing on two spools.

3. A generator according to claim 2 including drive means to uniformly move the tape of material from one spool to the other to continuously present new portions of the tape material over the internal opening of the output tube at a uniform rate of speed.

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