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ELECTROPHOTOGRAPHIC DEVELOPING PROCESS

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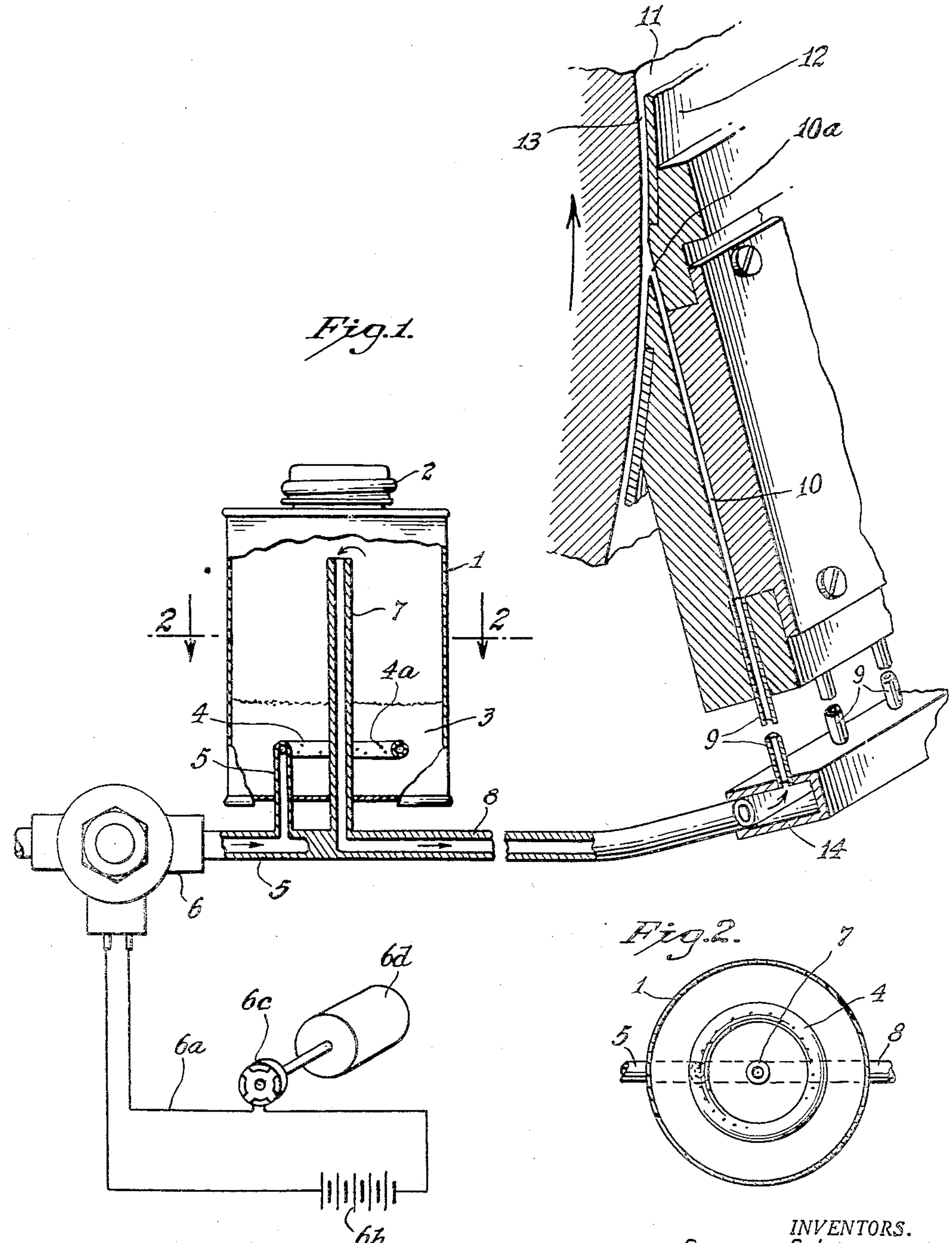

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2,872,338

ELECTROPHOTOGRAPHIC DEVELOPING PROCESS

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4 Claims. (Cl. 117—17.5)

This invention relates to an electrophotographic developing process.

In the art of electrophotography, sometimes called xerography, the latent image on the exposed electrophotographic surface is developed by flowing a developing powder over the surface. The powder adheres to the surface inversely in substantial proportion to the amount of light received by this surface so that a positive image is developed. This developed image is then transferred from the plate to a suitable carrier so as to produce the electrophotograph.

When the electrophotographic surface is provided by a flat plate which may be developed carefully by manual manipulation in an electrophotographic developing box or tray, electrophotographs of good quality are obtainable. When the electrophotographic surface is provided by a cylindrical electrophotographic plate or by a suitable flexible web or the like, and the powder is blown across the surface by an air stream, in the manner required by continuous electrophotographic equipment, trouble has been experienced in obtaining electrophotographs of the quality known to be obtainable in the case of manual manipulation. At the same time, it is very desirable to produce a fully satisfactory, continuously operating electrophotographic camera incorporating such a rotating cylindrical electrophotographic surface developed by powder carried by an air stream, because this permits the reproduction of a travelling object almost instantaneously with the developed image continuously transferred from the electrophotographic surface to a continuously travelling carrier web. Thus it is possible to provide an aerial camera producing a finished picture of the terrain traversed by an aircraft substantially instantaneously and without requiring the use of the usual aqueous photographic solutions with their attendant weight, bulk, and short storage life.

Among the things that determine the quality of an electrophotograph is, of course, an image that is developed substantially uniformly throughout without noticeable flow lines, agglomerations of the developing powder particles, and other similar defects. This type of defect has presented a problem in connection with the operation of continuous electrophotographic equipment and has been particularly apparent in connection with the production of continuous tone electrophotography. Apparently such troubles arise for various reasons, such as in the necessarily continuous operation of the powder cloud generator, the continuous conveyance of the powder from the generator to the location of its application to the travelling electrophotographic surface and at various other points in the equipment.

With the above in mind, one object of the present invention is to provide a general improvement on the development uniformity obtainable in connection with the continuous production of electrophotographs and particularly in the case of continuous tone electrophotographs. In achieving this overall object ancillary objects are involved such as an improvement in the operation of the necessary powder cloud generator when it operates under continuous conditions, an improvement in the art of conveying the powder cloud carried by the air stream to the development location, and an improvement in the manner in which the powder carried by the stream is applied at the developing location, all of such improvements being aimed generally at obtaining a uniformly distributed flow of the powder particles carried by the air stream over the continuously travelling electrophotographic surface in a manner free from localized concentrations or powder-starved zones and free from agglomerations of powder particles.

For the purpose of disclosing this new process the general elements of a continuous electrophotographic apparatus are disclosed by the accompanying drawings, Fig. 1 showing more or less in vertical cross section the various elements, and Fig. 2 being a cross section of the powder generator taken on the line 2—2 in Fig. 1.

These drawings show one form of developing powder cloud generator comprising an upstanding cylindrical container 1 having a screw cap closure 2 which may be opened so that the powder 3 may be placed inside of the container. This powder may consist of powdered wood charcoal which has been ground for from 20 to 50 hours in a ball mill. When microscopically examined its average particle size is seen to be on the order of 1 micron in diameter.

A header 4 is located inside of the container 1, this header comprising a horizontally positioned toroidal tube through which 16 uniformly interspaced holes *4a*, each 0.012″ in diameter, are drilled. The charcoal powder is used in a quantity which covers the header to a depth of about 3/8″ and the header is supplied with compressed air by a conduit 5 which comes from a valve 6 through which the conduit 5 is connected with a source of compressed air. Other compressed gaseous fluids may be used providing they do not chemically react harmfully with the powder, the equipment, or the electrophotographic plate, but air has so far proven to be satisfactory.

The compressed air ejected through the holes *4a* violently disturbs the powder 3 and fills the container 1 with a cloud of the powder particles suspended in the air, and the container has an exit near its top formed by a vertical, open topped, tube 7 which extends from the top of the container 1 downwardly. This tube connects with a conduit 8 which carries the flow to one or more, usually a plurality, turbulence tubes 9. As the flow passes rapidly through these turbulence tubes 9 turbulent flow conditions are established. The turbulence tubes are made of metal and the powder particles are triboelectrically charged. The turbulent flow condition also has the desirable effect of either deagglomerating or preventing agglomeration of the powder particles.

All of the turbulence tubes 9 connect with a manifold 10 where their individual flow characteristics, which would be undesirably jet-like, are transformed to a single wide flow which is ejected through a slit *10a*, the pointing direction of the flow being at a sharp angle to the rotating direction of the cylindrical electrophotographic surface 11. The correspondingly cylindrically shaped development electrode 12 defines with the surface 11 a relatively small development space 13 through which the powder cloud stream flows.

In the operation of this type of equipment the powder cloud generator must operate continuously, and the powder cloud stream must be carried as a continuous flow by the conduit 8, the turbulence tubes 9, the manifold 10 and, of course, the stream must flow through the slot-like orifice **10*a*** and the space 13. In some instances a settling chamber or other interposed equipment, generally indicated at **14**, may be interposed in the flow path. The extremely fine powder particles should be carried in the form of a uniform dispersion without the particles agglomerating, so that the individual jet-like flows produced by the turbulence tubes **9** are joined without loss of their turbulent character in the manifold space **10** and so that a uniform curtain-like flow of evenly dispersed particles is established in the space **13**.

In the practical operation of such equipment the above desirable operational characteristics are difficult to attain. The air jets from the holes *4a* in the powder generator tend to cut channels through the powder **3** so that with time the generated powder cloud decreases in density. The powder particles tend to agglomerate in the conduit **8** and in any space, such as is afforded by the part **14**, and such agglomerations are not always deagglomerated in the turbulence tubes **9**. The turbulent flows from the tubes **9** tend to convert to laminar flows in the manifold **10** with a consequent kinetic energy decrease permitting the powder particles to settle in the manifold space **10**. Also, this manifold space is not always adequate to form a transversely uniform or curtain-like form of flow for ejection through the orifice *10a*.

According to the present invention many if not all of the above troubles are decreased in severity or eliminated by causing the various flows to pulsate continuously. The pulsations may be applied by making the valve **6** a solenoid actuated valve which is connected in a circuit *6a* powered by a suitable electrical energy source *6b* and including a circuit interrupter *6c* rotated by a motor *6d*. The circuit interrupter is illustrated as being of the commutator type. Any suitable arrangement for periodically varying the pressure of the flow or for periodically interrupting the flow may be used.

In the practical operation of this process it has been found that pulses of 0.03 second in duration at the rate of 5 pulses per second substantially reduce the incidence of particle agglomerations which are visible to the naked eye in the finished electrophotograph. Such pulses may be obtained by timing the operating of the valve **6** so that it opens for 0.03 second and then closes with the intervals timed to produce 5 of these open periods per second. The pulse frequency may range from 3 to 10 pulses per second and the duration of each pulse, obtained by opening the valve, may vary as required by this range of frequencies to produce a pulsating flow.

The result is a pulsating flow through the holes *4a* in the powder cloud generator which reduces the tendency of the jets ejected through the holes *4a* to form channels through the powder **3**, thus tending to keep the powder generator operating at its initial efficiency for a longer period of time than was previously possible. The pulsating air stream carrying the suspension of developing powder particles travel through the conduit **8** with a reduced tendency toward agglomeration by the particles. The action of the turbulence tubes **9** is not interfered with and there is a tendency to maintain turbulent flow conditions within the manifold space **10**. Any tendency to agglomerate in relatively large interposed spaces, such as is provided by the element **14**, appears to be reduced. The tendency for the powder particles to precipitate in patterns within the manifold **10**, in front of the tubes **9**, is reduced. Furthermore, a uniform curtain-like flow appears to result within the space **13**. All of these advantageous results are believed to follow from the application of pulses to the usual powder cloud flow. In any event, there is a decided improvement in the quality of the finished image obtained when the pulsating condition is maintained.

Apparently this improved result is directly attributable either to preventing particle agglomeration or a deagglomerating effect which occurs before the powder is discharged over the electrophotographic plate to be developed.

It is apparent that the new process involves a new way for conveying the developing powder, comprising dispersing the powder in a gaseous fluid such as air and conveying the powder by flowing the fluid while causing the fluid to pulsate. This, in turn, provides a new developing process wherein the powder is flowed over the electrophotographic surface bearing the latent image by being carried by the gaseous fluid which is in a pulsating condition. This flow of fluid and powder is laterally confined by the various conduits so as to maintain its pulsating character at least up to the time it is caused to traverse the sufrace to be developed, and the pulsating condition is maintained during the actual development to a considerable degree due to the necessarily close spacing between the developing electrode **12** and the surface **11** being developed.

There are various kinds of electrophotographic developing powders and most if not all of these show the same tendency to agglomerate as does charcoal when used in a continuous type of equipment. The pulse duration and frequency may be easily varied so as to produce conditions which appreciably deagglomerate such particles. It is to be understood that where the term deagglomeration is used it is to be considered as meaning that in the final result a reduced tendency to agglomerate is observed. It is difficult to tell whether or not the particles first agglomerate and are subsequently deagglomerated or whether they are prevented from agglomerating at all when subjected to the pulsating flow condition of the present invention. The duration of the pulses may be adjusted by the use of circumferentially longer or shorter segments for the commutator arrangement *6c*, the frequency, of course, varying with the rotary speed of this device. Other more flexible arrangements may be substituted, it being well within the skill of the art to control the opening and closing of the solenoid valve as required.

The space of the part **14**, of course, represents a relatively large space where there is a pressure reduction, this also being true of the manifold space **10**. It is believed that the pulsations substantially assist in maintaining turbulence in such places or in some other fashion to provide the energy required to keep the powder cloud particles in suspension. The confined developing space **13** is another place where the vibration-like character of the carrier fluid assists in maintaining a uniform particle dispersion, this being done without affecting the attraction of the particles to the charged latent image support.

This application is a continuation-in-part of our application Serial No. 244,556, filed August 31, 1951, now Patent 2,725,304.

We claim:

1. A process for developing an electrostatic image on an electrically insulating surface, said process including dispersing an electrophotographic developing powder in a gaseous fluid and flowing said fluid and powder over said surface while causing said fluid to pulsate.

2. A process for developing an electrostatic image on an electrically insulating surface, said process including dispersing an electrophotographic developing powder in a gaseous fluid and flowing said fluid and powder over said surface while causing said fluid to pulsate, said powder comprising powdered charcoal having an average particle size not much larger than one micron in diameter and said fluid being caused to pulsate at a frequency of from 3 to 10 pulses per second.

3. A process for developing an electrostatic image on an electrically insulating surface, said process including passing a pulsating flow of a gaseous carrier through a layer of electrophotographic developing powder at a velocity causing particles of the powder to be dispersed in the carrier and thus producing a pulsating flowing mixture of the carrier and powder particles, confining said flow laterally so as to maintain its pulsating character and guiding the thusly confined flow to said surface, and causing said flow to traverse said surface.

4. A process for developing an electrostaic image on an electrically insulating surface, said process including passing a pulsating flow of a gaseous carrier through a layer of electrophotographic developing powder at a velocity causing particles of the powder to be dispersed in the carrier and thus producing a pulsating flowing mixture of the carrier and powder particles, confining said flow laterally so as to maintain its pulsating character and guiding the thusly confined flow to said surface, and causing said flow to traverse said surface, the particles of said powder having a tendency to agglomerate when conveyed by a continuous flow of said gaseous carrier and said pulsating flow having a pulse frequency which appreciably deagglomerates said particles.

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