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METHOD OF DEVELOPING ELECTROSTATIC IMAGE WITH FOAM LIQUID DEVELOPER

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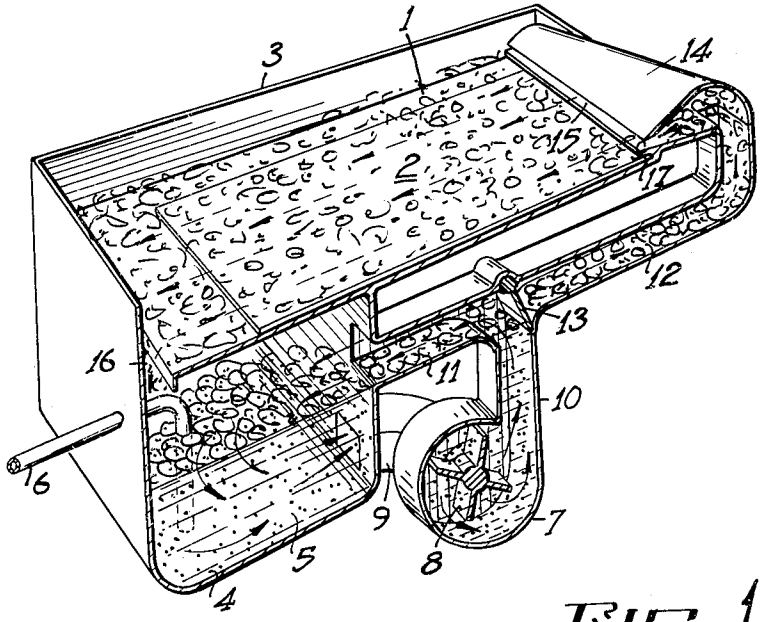

FIG 1

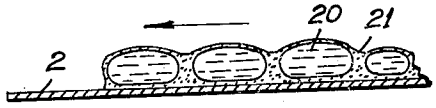

FIG 2

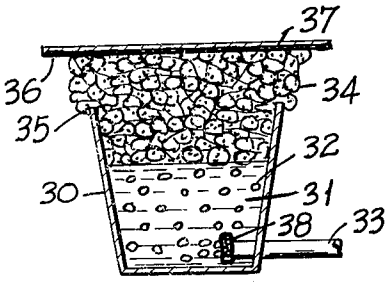

FIG 3

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METHOD OF DEVELOPING ELECTROSTATIC IMAGE WITH FOAM LIQUID DEVELOPER

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This application is a continuation-in-part of applicants' prior application Serial No. 763,016 now U.S. Patent 3,001,888.

This invention relates to foam developers for electrostatic images.

Development of electrostatic images is at the present time effected principally by three methods, the first of these consisting in the use of dry powders which are dusted onto the image and are subsequently fixed by heating or the like, the second method consisting in the use of a cloud of developer, and the third method consisting in the use of liquids which carry the developer material.

It has been shown that there are substantial advantages in using a liquid, since the pigments or other developer materials are free to move in the liquids of selected characteristic and also fixing of the image can take place without added steps such as the heating which was necessary heretofore.

A liquid developer should preferably be of such a nature that, while it allows free movement of the developer materials to the site where they are to be deposited, it should not be dangerously inflammable or explosive. Most of the liquid developers have a characteristic such that under suitable conditions they might be inflammable.

An object of the present invention is to provide improved developers so that this risk can be controlled or entirely removed, a further object being to provide certain improvements to the known process of liquid development such as more rapid development and better means of controlling the density or tone.

In the dry powder development method already known, a cascade principle has been used according to which mechanical objects such as beads are coated with the developed powder and these then apply the powder to the image as they roll over it, such a method having been found very advantageous in methods of dry powder development as the developer is mechanically brought into intimate contact with the image irrespective of some irregularities in the surface.

The present invention also envisages the use of a carrier phase for the developer, but instead of using a solid medium, the carrier is according to our invention a gas of suitable surface tension so that the developer can be carried on the surface of its globules and can thereby be deposited onto an electrostatic image as the carrier moves the developer in contact with it.

A foam developer for electrostatic images according to our invention can therefore comprise a gaseous carrier phase and a liquid developer phase, the liquid developer phase being located on the surface of the gas bubbles when shaken up to produce a foam.

According to a more specific form of the invention a foam developer for electrostatic images comprises a carrier phase and a developer phase, the carrier phase consisting of a non-inflammable gas, the developer phase comprising a non-polar liquid having a volume resistivity of not less than 10^{10} ohm-centimeter and a dielectric constant of not greater than three, the developer substance having a pigment such as phthalocyanine blue suspended in it on the particles of which is a coating forming a control and fixing agent such as a resin or an oil

which is only sparingly soluble in the developer liquid or remains deposited on the surface of the pigment substance when the carrier liquid is evaporated whereby when the liquids are shaken up to produce an emulsion, the globules of the said carrier phase have a film of the developer phase thereon but removable therefrom by the field of an electrostatic image.

The importance of this will at once be realized when it is appreciated that a non-inflammable developer carrier can be used, it being for instance necessary only to combine a developer with an inert gas which, when shaken up, will cause the gas to carry the developer.

It will be realized that if for instance, a substance such as kerosene is shaken up with a gas, a pigment and bonding medium having previously been incorporated in the kerosene according to the method of preparing liquid developer substances, the two phases namely kerosene and gas will not be miscible, and the effect will be to have a separation when the two phases are first mixed together, but when the mixture is shaken the gas will be broken up into globules which will be isolated by a film of the kerosene base developer, and the size of these globules can then be controlled by the amount of agitation and in part by the relative ratios of the two phases.

From the foregoing it will be realised that an object of the present invention is to develop an electrostatic image by an improved process in which the liquid developer is presented to the surface of the sheet supporting the electrostatic image by means of bubbles which maintain a surface film of the liquid.

The effect obtained results from the use of the bubbles as a flexible or cushioning applicator which makes available its surface film of liquid in good contact with the electrographic sheet.

There is the further advantage that a conductive gas may be used to form the bubbles of foam so that an effective conductive electrode is established which constricts the electric field in relation to the image charge and thereby accelerates deposition of the developer material from the liquid film.

By way of explanation, the developer particles and fixing resin are contained in an insulating liquid; in combination these comprise the developer and the material actually deposited on the image, from the liquid, are the pigment or dye particles and the resin. The totality of developer comprising liquid, particles and resin is maintained as a surface film comprising the interface between the gas bubbles and each other as well as the external air. It is therefore an object of this invention to use this bubble-supported film to develop the electrographic image more effectively than heretofore.

To enable the nature of the invention to be fully appreciated, it will now be described with reference to the accompanying drawings in which:

FIG. 1 is a perspective view in central longitudinal section of a developer tray according to one form of the invention,

FIG. 2 is a sectional view depicting how the liquid developer phase can be carried across the surface by the gaseous carrier phase, and

FIG. 3 is a sectional view showing how the foam can be generated in a vessel and the paper to be developed passed over it to contact the foam.

The developer mechanism depicted in FIG. 1 comprises a tray 1 onto which the paper 2 to be developed is placed, the tray 1 being housed in a casing 3 in which the tray 1 is arranged with a slight downward slope to cause the developer to flow across the tray 1 in one direction.

The casing 3 contains a developer tank 4 which carries in it the developer liquid 5.

The gas is trapped in this liquid or fed in through the pipe line 6 under pressure.

To mix the gas and liquid developer a pump 7 is provided the rotor 8 of which can be driven in any suitable manner, the pump 7 being connected to the developer tank 4 by an intake duct 9 which allows the developer to flow into the pump, the developer being discharged from the pump through the duct 10 to a two-part duct 11–12, the two-part duct being divided by a directing vane 13 which can be placed either into the position shown in FIG. 1 or which can be swung over towards the left.

The part 11 of the two-part duct is disposed to feed liquid developer displaced by the pump 7 back into the developer tank 4 and when the mechanism is set in the manner indicated, operation of the pump 7 will circulate the two phase developer continually through the tank and in this way will ensure the mixing of the phases.

The part 12 of the two-part duct leads to a nozzle 14 which extends across the higher end of the tray 1 and has a narrow opening 15 directed across the tray so that when the directing vane 13 is displaced to its opposite position, the liquid will be drawn from the developer tank 4 by the pump 7 and will be pumped along the path of the dotted arrows in the duct 12 into the nozzle 14 and from there will issue across the paper 2 and the tray 1 in the direction of the dotted arrows, the developer leaving the tray 1 through the gap 16 between its end and the wall of the developer tank 4.

In this way by appropriately positioning the directing vane 13, the developer can be maintained in an emulsified or foamed state by circulating the developer through the pump and the developer tank 4 in the direction of the full line arrows shown in the drawings, and at this stage no flow will take place across the tray 1 from the nozzle 14.

A paper to be developed can then be simply placed into position as shown, preferably by engaging its leading edge into a notch 17 in the tray 1 and the directing vane 13 is then simply swung over to the other position and the emulsified developer will be pumped through the nozzle 14, out of the openings 15 to flow rapidly across the surface of the paper being developed and the tray and back into the developer tank 4, the directing vane 13 being simply swung back to its other position immediately after development has been completed which it will be found can take place in a matter of a few seconds, the paper being then simply removed.

In the embodiment described, sufficient liquid must remain in circulation to ensure the required movement of the gas trapped in the liquid, which can be achieved by maintaining approximately equal volumes of gas and liquid with the gas being replaced in the liquid at a rate to keep this balance.

Referring to FIG. 2 the paper is again represented by the numeral 2 but the gaseous phase is designated as 20 while the developer phase is designated as 21, the developer 21 and bubbles of the gas 20 moving across the surface 2.

In the device shown in FIG. 3 a vessel 30 contains a liquid developer 31 into which gas 32 is blown through a pipe 33.

The foam 34 formed by the gas 32 bubbling through the developer liquid 31 rises above the upper edge 35 of the vessel and the image on the photoconductor surface 36 on the base 37 is developed by subjecting it to the foam 34.

A sintered glass bubbler 38 is positioned over the gas inlet pipe 33.

According to this invention a froth or foam is the more or less stable extended air/liquid interface arising when bubbles persist or develop at the surface of a liquid due to aeration, agitation or ebullition. A large film surface of liquid may be presented to the gas phase, so that foam is primarily a labile system owing to the tendency for the interface to be reduced to a minimum.

From the foregoing it will be realized that foam can be formed for example by blowing air through a liquid developer with or without agitation means, and we have found that an electrostatic image can be developed by passing the sheet carrying the electrostatic image over the top of the foam layer, or by passing the foamed developer over the paper. In the case of the embodiment shown in FIG. 3 we have discovered that a charged sheet when brought into close proximity to the foam layer tends temporarily to compress the foam until a critical distance is reached whereupon the foam appears to erupt and rise to the charged sheet. The sheet can then be raised to its first "compression" position and the foam continues to adhere in bulk. This effect we have used to enable the developer-laden foam to be brought into contact with the sheet in order to develop the electrostatic image.

(1) As an example of the invention, a developer liquid was made up which incorporated an epoxy resin known as Beckosal P786 supplied by Reichhold Chemicals Incorporated. 20 milliliters of this resin, based on a mineral turpentine solution, were further diluted in 200 milliliters of mineral turpentine to which was added 20 milliliters of a mineral turpentine suspension of the pigment Lithol Red in the proportion 2 percent by volume and 2 percent by volume lithographic varnish. This pigment and varnish constituted the coloring and fixing matter for the development and the mineral turpentine was the developer vehicle. The foam was produced by passing dry nitrogen gas through a sintered glass bubbler in the developer liquid. This ensured the production of a continuous foam frontal surface and its presentation to the latent electrostatic image when the electrogrphic paper was passed over the surface of the foam.

(2) In the second example of our invention an electrostatic image was developed on an electrographic paper by contacting the paper with the developer foam the foam being produced from a developer liquid as described below:

The developer liquid was prepared by dissolving 5 grams of an hydrogenated rosin in 100 milliliters of Cumene (iso-propyl benzene) to which was added for coloring one milligram of phthalocyanine blue. Dry air was bubbled through a sintered glass bubbler placed in this developer so that a continuous foam front was generated and caused to rise to come into contact with the electrostatic image on the electrostatic image on the electrographic paper.

(3) In the third example of the invention a latent electrostatic image on an insulator sheet was prepared by subjecting the surface of the sheet to contact with a foam surface generated by passing a gas through a liquid developer made in the following manner:

5 grams of the resin known a Pentacite 423 made by Reichhold Chemicals Incorporated were ground up and dissolved in 200 millieters of kerosene to which was added 2 milligrams of finely divided aluminum powder. Dry carbon dioxide gas was bubbled through a metal bubbler placed in the developer liquid bath so as to form a continuous foam above the surface of the liquid. The electrostatic image was brought into contact with this foam surface, first compressing and then attracting the film of developer carried on the surface of the bubbles, following which the developer particles in this case aluminum powder were attracted to the image and produced a visible image.

It will be realized that with a foam developer as described, the danger of fire can be materially reduced or completely eliminated because of the addition of the non-inflammable substance to the inflammable substance, and in this way a developer is provided which not only has improved developing properties but also materially reduces any fire hazard which might otherwise be present, although in practice it has been found that fire risk

is negligible even with a carrier base of relatively inflammable liquid.

It will be obvious of course that, apart from the reduction of fire hazards, there is also a substantial reduction of toxicity if the developers should have this characteristic because the total volume of the foam developer contains a correspondingly smaller volume of the liquid developer substance. An effect of these developers is as said, to give good tone control, as the developer phase can have certain electrical characteristics, whereas the carrier phase can have other characteristics, and by varying the characteristics of particularly the carrier phase it is possible to regulate the rate of bleed-off of the image charge for toning purposes. Similarly the thickness of the developer coating on the carrier globules, and the resistivity of the developer liquid itself will provide further control means.

It is of great importance to note that as the globules of the carrier phase have deformable walls, they can accommodate themselves more readily to surface inequalities in the medium being developed and thus the improved developer greatly improves the process over the dry developer and rigid bead systems.

What we claim is:

1. A method of developing an electrostatic image which comprises suspending pigment particles in a liquid having an electrical resistivity of not less than 10^{10} ohm-centimeter and a dielectric constant of not greater than three so as to form a liquid developer adapted to develop an electrostatic image, dispersing in said liquid developer a gas which is insoluble in said developer, agitating the liquid developer to produce a foam whereby the liquid developer is carried on the surface of globules of the gas in such foam, and flowing said foam over a base having an electrostatic image thereon to deposit said pigment on said image.

2. A method of developing an electrostatic image which comprises coating pigment particles with a control and fixing substance, suspending the coated pigment particles in a liquid to form a liquid developer adapted to develop an electrostatic image, said liquid having an electrical resistivity of not less than 10^{10} ohm-centimeter and a dielectric constant of not greater than three and having the property that the control and fixing substance is at most slightly soluble therein, dispersing in such liquid developer a gas which is insoluble in said developer, and agitating the liquid developer to produce a foam whereby the liquid developer is carried on the surface of globules of the gas in such foam, and applynig said foam to a base having an electrostatic image thereon to deposit said pigment particles on said image.

3. A method of developing a latent electrostatic image on a surface comprising forming a liquid developer phase containing a developer substance in a non-polar liquid and adapted for developing an electrostatic image, said liquid having an electrical resistivity of not less than 10^{10} ohm-centimeter and a dielectric constant of not greater than three, the developer substance including pigment particles having as a coating therefor a fixing agent which is only sparingly soluble in the developer liquid whereby when the non-polar liquid is evaporated the fixing agent remains deposited on the surface of the developer substance, introducing into the liquid phase an inert gaseous carrier phase which is insoluble in said liquid phase and agitating said phases to produce a foam in which individual globules of gaseous carrier have a film of the developer phase thereon, and contacting the surface having the latent electrostatic image with the thusly produced foam to deposit said pigment particles on said image.

4. A method as claimed in claim 3 wherein said gaseous carrier phase is a non-inflammable gas.

5. A method as claimed in claim 3 comprising continuously agitating said phases to produce said foam and selectively feeding a portion of the foam to the surface with the electrostatic image thereon when it is desired to develop the latter.

6. A method of developing a latent electrostatic image on a surface by use of a liquid developer adapted for developing said image and containing a developer substance including pigment particles coated with control and fixing substances suspended in a liquid having an electrical resistivity of not less than 10^{10} ohm-centimeter and a dielectric constant of not greater than three and in which the developer substance is at most slightly soluble, said method comprising blowing an insoluble and inert gaseous medium upwardly through said liquid developer to form an upper foam surface in which globules of the gaseous medium are isolated from one another while being coated with a thin film of the liquid developer, and developing the electrostatic image on said sheet by contacting the sheet with the foam surface to deposit said pigment particles on said image.

7. A method of developing a latent electrostatic image on a surface by use of a liquid developer adapted for developing said image and containing a developer substance including pigment particles coated with control and fixing substances suspended in a liquid having an electrical resistivity of not less than 10^{10} ohm-centimeter and a dielectric constant of not greater than three and in which the developer substance is at most slightly soluble, said method comprising blowing an insoluble and inert gaseous medium upwardly through said liquid developer to form an upper foam surface in which globules of the gaseous medium are isolated from one another while being coated with a thin film of the liquid developer, bringing the surface having the electrostatic image thereon into contact with the foam surface and compressing the foam surface to a determinable extent whereafter the foam surface erupts and rises towards the surface having the electrostatic image thereon, and raising the surface having the electrostatic image thereon as the foam surface rises with a portion of the foam surface adhering to the surface with the electrostatic image thereon to deposit said pigment particles on said image.

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WILLIAM D. MARTIN, *Primary Examiner.*