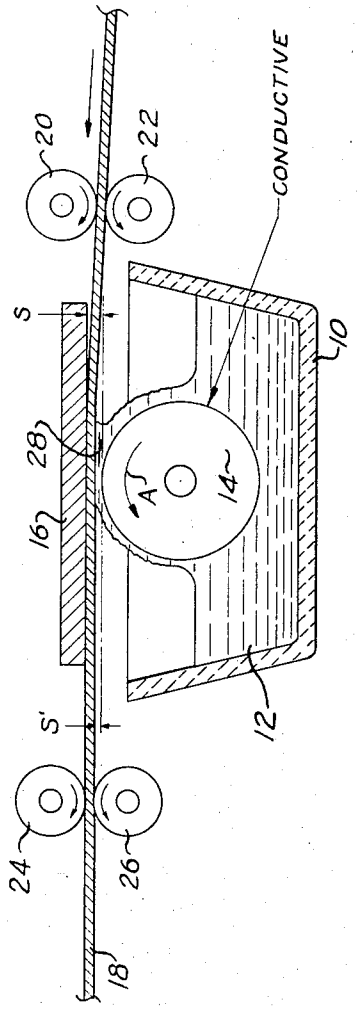
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LIQUID DEVELOPMENT OF ELECTROSTATIC IMAGES

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LIQUID DEVELOPMENT OF ELECTROSTATIC IMAGES

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This invention relates to the deposition of particles upon the surface of a moving sheet in accordance with a latent electrostatic pattern previously formed thereon, and especially in situations where it is desirable to employ a liquid as the carrier for the particles during deposition.

The treating of an electrostatically imaged sheet with a liquid developer having electrostatically attractable particles dispersed therein is a well-known procedure and is usually carried out by immersing the sheet in a bath of the developer.

In certain situations, however, especially where the sheet to be developed is being conveyed through automatic treating equipment such as that provided in many electrostatic copiers, it may be preferable not to immerse the sheet but rather to apply the liquid only to the imaged surface, and such an arrangement is illustrated and described in U.S. Patent No. 3,203,395 to R. F. Liller. There the sheet is arranged with its electrostatically imaged surface directed downwardly, and is floated on a bead of liquid raised to a position above the moisture level in a tank by means of rollers, so that only the downwardly facing surface of the sheet comes into contact with the liquid.

The present invention is based upon the principle that improved deposition can be obtained by means of a conductive field control member placed very close to, but accurately spaced from, the surface of the sheet to be developed, and embodies a means for maintaining an accurate minimum spacing relationship between such a field control member and the sheet surface under the relatively unstable kinetic circumstances represented in progressive application of developing liquid to the bottom surface of an electrostatic image on a sheet by means of a roller.

It may be noted at this point that a conductive field control member, placed close to the photoconductive surface during development not only speeds deposit but also assists in providing a uniform deposit over large solid areas and avoids edge effects. By "edge effects" is meant the electrical field phenomenon which results in a low intensity deposit found in the centers of large charged areas, which are intended to show a solid, uniform density when developed, but instead display dark edges shading to grey to white centers.

This invention, in the presently preferred form, provides a roller dipping into a liquid bath, which roller is operated at speeds such that a hydrodynamic pressure is created against the surface of the sheet, holding the latter against a back guide which is located at a fixed, determinate spacing from the closest point of roller approach. The roller is made conductive, or at least has a highly conductive surface layer, which provides the field control effect required at the point where electrostatic deposit of particles is occurring. The motion of the roller in addition to providing the hydrodynamic forces for sheet control, also renders the liquid action sufficiently turbulent to provide a constant changing and replenishing action which will forestall the possibility of the developing liquid's reaching a starved or depleted condition at the developing location where rapid particle deposit is occurring due to the presence of the highly efficient field control.

The single figure of the drawing is a schematic section of one form of device for developing an electrostatically imaged sheet by treatment with a liquid developer in accordance with the present invention.

Referring to the drawing, there is illustrated therein a tank **10** containing a bath **12** of liquid developer of the type designed for use with electrostatic deposition procedures, and having dispersed therein minute electroscopic particles which will deposit upon electrostatically charged areas of a sheet surface.

Rotatably mounted upon an axis fixed with respect to the tank **10** is a roller or cylinder **14**, the lower portion of which dips into the bath **12**. The cylinder **14** is driven by any suitable power means (not shown) in a direction of rotation indicated by the arrow A. The cylinder **14**, or a layer of substantial thickness on the exterior thereof, is of conductive material, for example brass.

Fixedly mounted above the roller is a guide plate **16**. Sheets **18** with latent electrostatic charge images on their lower surfaces are caused to pass between the roller **14** and the guide plate **16** by in-feed rollers **20**, **22** and pull-out rollers **24**, **26**.

The speed of the sheet, as determined by the speed of rollers **20**, **22** and **24**, **26**, is so related to the surface speed of the cylinder **14**, that the liquid developer is washed up against the lower surface of the sheet **18** forming a constantly available bead of liquid indicated by numeral **28**. It will, of course, be understood that the cylinder **14** normally rotates at a speed such that its surface is travelling rapidly relative to the surface of sheet **18**, and while the upper portion of the cylinder surface is moving in the same direction as the sheet in the form shown, the arrangement can also be made to work effectively when a reverse direction of rotation is used. In either case, the action is such that a hydrodynamic force is created whose effect is centered in the vicinity of the bead **28**, and which acts to hold the sheet **18** reliably against the bottom surface of the guide plate **16** during its transit across the top of the tank **10**.

From the drawing it can be seen that there is a predetermined spacing S between the bottom surface of the guide plate **16** and the zenith point of the cylinder **14**, due to their fixed mounting relationship. There is likewise a spacing S′ between the sheet surface and the zenith point of the cylinder **14** which under normal circumstances may vary due to uncontrolled travel of the sheet. In order to provide the desired field control effect as a result of the conductive nature of the cylinder **14**, this spacing S′ must be quite small and must be maintained with a certain degree of accuracy. A distance of about $\frac{1}{32}$ inch has been found about the optimum in practice with paper sheets of usual thickness and electrical properties, and a range of spacing of about $\frac{1}{64}$ to $\frac{1}{8}$ inch is found to be the range of effective field control values. For convenience, spacing within the general ranges identified may be referred to as effective field control spacing. As the spacing S is made smaller for increasingly effective field control, local random variation in S′ becomes of even greater importance. For example, a variation of $\pm.005$ inch in S′ if $S=\frac{1}{64}$ is highly undesirable whereas if $S=\frac{1}{8}$ inch the same fluctuation in S′ would create virtually no visible differences in the developed image.

To minimize local random variations it is desirable to cause the sheet to conform very closely to the guide member so that the precision attainable in the mounting of the guide member will be effective to minimize variations in S′, and this is admirably achieved according to this invention by the hydrodynamic action of the liquid developer itself.

The use of the hydrodynamic action of the developing liquid to maintain the surface of the electrostatically imaged sheet against a guide which insures accurate spacing from the conductive field control surface of the roller **14** makes it possible to employ a field control technique on a practical basis with very close spacing of the field

control member, and thereby produce imaging of the highest quality. It is, moreover, possible to accomplish these results in such a way that the need for complex means for assuring proper positioning and adequately close tolerances of spacing of the sheet across its whole surface is avoided. The hydrodynamic effect of the developing liquid acts automatically and simultaneously at all points on the sheet which are in the developing zone by reason of being exposed to the liquid.

In certain respects the field control aspect of the equipment assists development, while in other respects it has been found to inhibit it. In general the closer the field control conductor is placed to the photoconductive surface the more rapidly the electroscopic particles are deposited on the charged areas of the sheet. When very close spacing is involved, however, this deposit can be so rapid that the developer liquid available in the area tends to become stripped of particles so that subsequent image areas are starved and do not receive appropriate deposits. This effect is aggravated to some extent by the fact that changing the liquid adjacent the sheet surface necessarily becomes more difficult the closer the sheet surface is brought to the field control conductor since there is a smaller cross sectional area available for introduction of fresh liquid.

Due to the relationships stated in the foregoing paragraph it is important, especially when the closer spacings are used, to purposefully move the liquid developer in a manner that insures adequate rapid replacement to prevent the starvation phenomenon alluded to. In the presently disclosed form of the invention, the rapid rotation of the cylinder **14** is at a rate sufficient to provide pronounced turbulence in the bead **28** so that the gap between the sheet **18** and cylinder **14** is continually flooded with fresh developer liquid and rapid exchange of fresh particle-charged developer for stripped developer is assured. The actual minimum rate of rotation of the cylinder to provide this replenishment depends on a number of factors such as cylinder diameter, depth of cylinder dip into the liquid, and sheet speed, but the speed producing proper turbulent flow can be readily ascertained both by observing the character of the bead **28** and by inspecting the development results.

While only the roller **14** has been referred to as conductive, it is found beneficial in some instances to actually apply a voltage across the gap between the roller and the surface of the sheet, in which case the guide plate **16** is also made conductive and a source of EMF is connected both to the cylinder **14** and to the guide plate **16**.

It will be understood that various configurations and structural arrangements may be provided, including for example a plural cylinder arrangement such as that illustrated in the said U.S. patent, provided that hydrodynamic forces are generated within the developing fluid itself by one or more of the rollers, which forces act upon the sheet to hold it against a guide surface appropriately adjacent to but spaced from the field control effect of the conductive roller surface, the spacing being at an effective field control value.

While preferred embodiments of the invention have been described and illustrated, it is to be understood that these are capable of variation and modification. Accordingly, the aim in the appended claims is to cover all such variations and modifications as may fall within the true spirit of the invention.

What is claimed is:

1. A method of developing electrostatic latent images on sheet surfaces which comprises:

mounting a cylinder with a conductive surface at a level to dip into a bath of developer liquid containing particles electrically attractable to areas on the surface of the sheet;

mounting a guide member above said cylinder in fixed relation thereto with its closest point of approach to the cylinder surface at a location defining therewith an effective field control spacing;

passing a sheet, whose surface has been electrostatically imaged, between the guide member and the upper part of the cylinder with the imaged surface towards the cylinder; and

rotating the cylinder in a direction and at a speed sufficient to raise liquid developer from the bath into the gap between the cylinder and the guide member and to generate hydrodynamic forces holding the sheet firmly upwardly against the guide member as it passes between the cylinder and the guide member.

2. A method as set forth in claim **1** in which the speed of rotation is at a value sufficient to insure turbulent flow in said gap with consequent rapid replacement of the developer liquid at the development location.

3. A device for developing electrostatic latent images on sheet surfaces which comprises:

means providing a bath of liquid developer containing particles electrically attractable to areas on the surface of the sheet;

a cylinder with a conductive surface rotatably mounted to dip into a bath of developer;

a guide member mounted above said cylinder in fixed relation thereto with its closest point of approach to the cylinder surface at a location defining therewith an effective field control spacing;

means for passing a sheet, whose surface has been electrostatically imaged, between the guide member and the upper part of the cylinder with the imaged surface towards the cylinder; and

means for rotating the cylinder in a direction and at a speed sufficient to raise liquid developer from the bath into the gap between the cylinder and the guide member and to generate hydrodynamic forces holding the sheet firmly upwardly against the guide member as it passes between the cylinder and the guide member.

4. A device as set forth in claim **3** in which the means for rotating the cylinder drives the same at a speed such that the flow of liquid developer in and around said gap is turbulent with consequent rapid replacement of the developer liquid at the development location.

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