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Mandeville

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[54] APPARATUS FOR DRYING AN ELECTROPHOTOGRAPHIC SUPPORT

[75] Inventor: **Arthur R. Mandeville,** South Hadley, Mass.

[73] Assignee: **Scott Paper Company,** Delaware County, Pa.

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[52] **U.S. Cl.** .....**34/150,** 34/151, 95/89 R

[51] **Int. Cl.** **F26b 13/00**

[58] **Field of Search** 34/150, 151, 23; 95/896; 117/119.8

[56] **References Cited**

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Primary Examiner—Carroll B. Dority, Jr.

Attorney—William J. Foley, Martin L. Faigus, John W. Kane, Jr., John M. Sheehan and John A. Weygandt

[57] **ABSTRACT**

A method for drying an electrophotographic support element containing on its front surface a latent electrostatic image which has been developed in a liquid medium, in which the support element is placed on a downwardly inclined foraminous member so that its back surface contacts the foraminous member and its front surface is directed away from the foraminous member, and cool air is circulated over the front surface and the back surface of the support element so as to evaporate the volatile components of the liquid medium from the support element. Apparatus for drying, in accordance with the method described, an electrophotographic support element containing on its front surface a developed latent electrostatic image, including means to circulate cool air over the front and back surfaces of the support element held in an inclined position in a drying chamber. The method and apparatus are particularly useful for drying support elements which are of unusually large size and weight and which have toned images of a type rendering the support elements suitable for use as lithographic masters or offset printing plates on a printing press.

4 Claims, 4 Drawing Figures

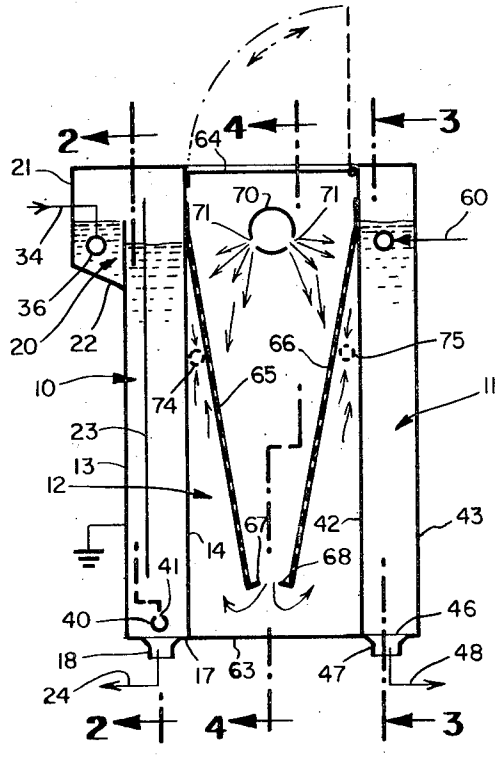


Fig. 1

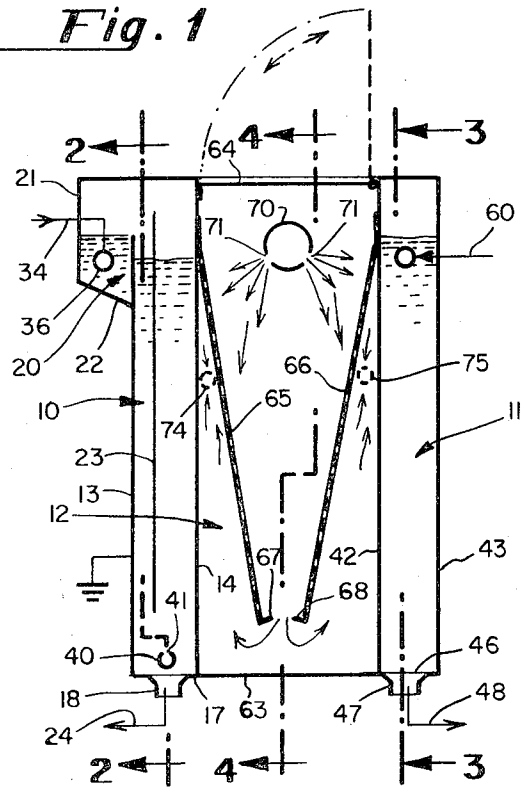


Fig. 2

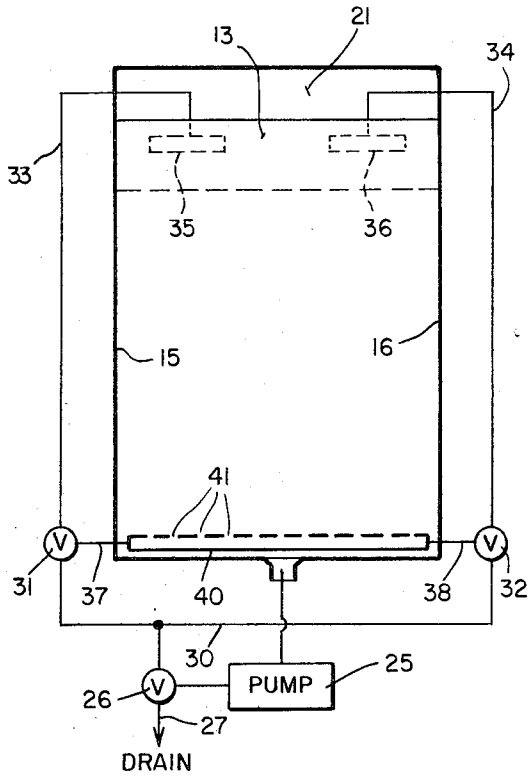
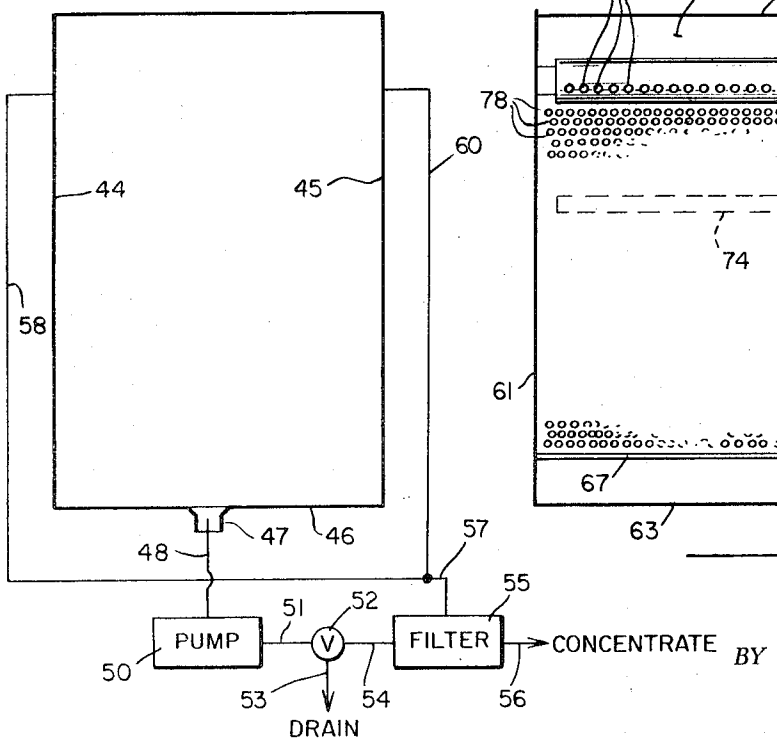


Fig. 3



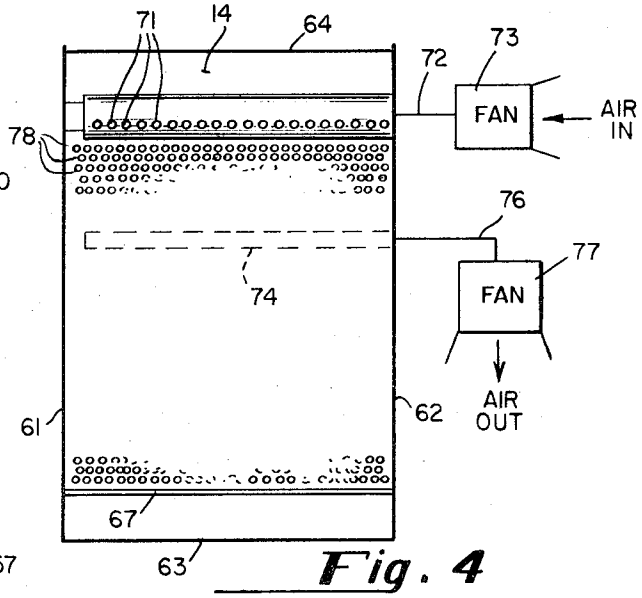


Fig. 4

INVENTOR.
Arthur R. Mandeville

BY

Stanton T. Kelley

ATTORNEY.

APPARATUS FOR DRYING AN ELECTROPHOTOGRAPHIC SUPPORT

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a method and apparatus for drying an electrophotographic support element containing on its front surface a latent electrostatic image which has been developed in a liquid medium. In particular, this invention is concerned with the drying of a support element which has been immersed in and withdrawn from a developing solution to develop the image in a way which more uniformly covers the imaged areas of the support element with toner particles.

2. Description of the Prior Art

In the past, electrophotographic support elements, such as copy sheets and the like coated with a photoconductive medium, having latent electrostatic images thereon which were developed and rendered visible by a liquid toning medium, have been dried by applying heat thereto to evaporate the volatile components of the liquid toning medium or developing solution and to leave residual pigmented toner material in image areas of the support element. Such support elements were often run through the nip between squeegee rolls to initially remove excess liquid toning medium or developing solution from the surface thereof. Alternatively, air doctors were utilized for thIs purpose. Contrary to dry or powdered tones mixer mixes, such liquid toning media or developing solutions have not required fusing to permanently adhere them to the support element.

One of the shortcomings of such toning processes has been the failure of large imaged areas to be developed uniformly, that is, to obtain uniform solid fill instead of an "edge effect" or a highly toned boundary. Moreover, such support elements, when wet toned or developed, had insufficient thickness of toner material in the image areas to withstand action on an offset lithographic printing press for a reasonable time. In addition, where greater relief of image areas from background areas was desired, it could not be obtained by liquid developing solutions. However, the dry toning systems using pigmented resinous powder for rendering the image visible did not provide the desired image resolution and sharpness of detail, which can be obtained from a liquid toning process. However, the dry systems are more convenient in that they merely require fusing rather than pre-drying to attach the toner particles to the support element.

The difference between such toning systems has largely stemmed from differences in the nature of the developing or toner material itself. Dry toners include fusible, pigmented resin particles which melt, coalesce and adhere to the support element when subjected to sufficiently high temperature, whereas liquid toners include ink formulations or very fine pigment suspensions in a carrier liquid which is usually highly volatile to facilitate rapid drying. The particle size of the pigmented power in a dry toner is usually quite large compared to that of the pigment particles in a liquid toner and, accordingly, when fused, a dry toner provides an image with greater body or depth of toner.

It has now been discovered that a latent electrostatic image can be developed by a liquid developing solution containing fusible pigmented resinous particles of a size and type normally used in dry toners. Such particles normally settle out in the carrier liquid so that turbulent conditions must be maintained during mixing thereof to maintain the particles in suspension, and the liquid developer is preferably circulated over the support element during development of the image thereon. However, drying of the resulting image and the support element on which the image is disposed must be accomplished in a manner which avoids disturbing the image or exerting disruptive forces upon the pigment particles forming the image. This necessarily implies that no squeegee rolls can be used to remove excess liquid developing solution from the support element, as such rolls would contact and disrupt the developed or toned image which is highly unstable until fused. In addition, it has been found that heat, whether applied in radiant form, or by conduction, or by convection from heated air passed over the support element, causes the developer material to run off of the imaged areas into the non-imaged areas, resulting in a loss of resolution and a streaked appearance.

In view of the above difficulties and shortcomings of prior art drying techniques and apparatus, it was completely unexpected and surprising to discover a new and improved method and apparatus developed for drying such a support element having on its front surface developed latent electrostatic image.

Thus, a principle objective and advantage of this invention is to dry an electrophotographic support element having on its front surface a latent electrostatic image, which has been substantially uniformly covered with toner particles, without losing image resolution or causing streaking.

It is a further object and advantage of this invention to dry an electrophotographic support element having on its front surface a developed latent electrostatic image of a nature such that, after fusing, the support element may be used as lithographic printing plate on an offset press.

SUMMARY OF THE INVENTION

The present invention is a method and an apparatus for drying an electrophotographic support element containing on its front surface a latent electrostatic image which has been toned and rendered visible by immersion of the support element in a liquid developing solution comprising a mixture of charged toner particles in a carrier liquid. In the method of the invention, the support element is placed on a downwardly inclined foraminous member so that its back surface contacts the foraminous member and its front surface is directed away from the foraminous member. Air is circulated over the front surface and the back surface of the support element so as to evaporate the carrier liquid and to leave the toner particles attached to the support element. Air Is preferably sequentially circulated over the front surface and then over the back surface of the support element. Where the support element is substantially vertically suspended in the developing solution when it is immersed, it is preferably inverted endwise after it is withdrawn from the developing solution and prior to being placed on the foraminous member. The

apparatus of the present invention includes wall means defining a drying chamber and means for supporting the support element in a downwardly inclined position in the drying chamber so that the drying chamber is partially divided into at least two compartments by the support element. At least one end of the support element is spaced from the wall means, preferably that portion thereof which defines the bottom of the drying chamber, to leave a communicating passageway between the compartments in the drying chamber. Air inlet means and air outlet means are disposed on opposite sides of the support element, and circulating means are provided for creating a flow of air from the air inlet means to the air outlet means through the drying chamber.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional side elevation view of developing apparatus, which includes an embodiment of the drying apparatus of the present invention which is capable of accomplishing the method of the present invention.

FIG. 2 is a sectional elevation view taken along line 2—2 of FIG. 1, showing the developing chamber of the developing apparatus used in the development of the image on the support element to be dried.

FIG. 3 is a sectional elevation view taken along line 3—3 of FIG. 1, showing the rinsing chamber of the developing apparatus used in the development of the image on the support element to be dried.

FIG. 4 is a sectional elevation view taken along line 4—4 of FIG. 1, showing the drying apparatus of the present invention in greater detail.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The method and apparatus of the present invention are used to dry an electrophotographic support element which has been immersed in a liquid developing solution in order to develop a latent electrostatic image on one of its surfaces. However, the invention has found particular utility and, indeed, is practically necessary for drying support elements containing latent electrostatic images which have been developed and rendered visible in a unique manner in order to permit the support elements to be utilized as lithographic printing plates on an offset press.

Briefly, this unique development process comprises contacting the surface of the support element which contains the latent electrostatic image with a liquid developing solution, which has toner particles therein which are preferably of a size and density such that they readily settle in the carrier liquid portion of the liquid developing solution upon cessation of turbulence in the liquid developing solution. Such a liquid toner solution is to be contrasted with one having pigment or toner particles of sufficiently small size and density as to be substantially permanently held in suspension by Brownian movement. The contact with the liquid developing solution described is maintained for a period of time sufficient to permit all portions of the electrostatic image to be rendered visible. This normally means that portions of the electrostatic image will be overdeveloped, that is, they contain more charged toner particles than is required to render the image visible, while other portions of the electrostatic image are merely fully developed. Ideally, enough of these large toner particles are attached to imaged portions of the support element to completely cover the imaged portion. The particles which are attached are of a fusible resinous nature as well as being pigmented so that they provide a body of material in the image area which, when fused and adhered to the support element, is capable of withstanding rigorous treatment and long service on a printing press and which, in instances where desired, can be made to have a relative high degree of surface relief, depending on the particular form of printing to be carried out or other use which is desired. However, inevitably excess toner particles become attached to some imaged portions of the support element due to factors such as the shape of the charged image portion, which often influences the amount or the distribution of charge in the imaged area, or the entrainment of some toner particles with others held to the imaged area by electrostatic charge.

Therefore, in the course of the development process, the support element is withdrawn from the liquid developing solution and subjected to a rinsing operation to remove excess toner particles from portions of the support element, including stray toner particles in background areas of the imaged surface as well as excess toner particles in image portions of the imaged surface. This is accomplished by immersing the support element in a rinsing solution and by circulating the rinsing solution over the surface of the sheet support element. The result of the above-described developing process is the formation of a developed image on the support element which is more clearly visible and which has improved uniformity of coverage with toner particles so that, when the image is eventually fused to coalesce the toner particles together and to attach them to the support element, the image areas will be uniformly pigmented and will have a more uniform body as evidenced by height or surface relief. A typical carrier liquid for the liquid developing solution, which also serves satisfactorily as the rinsing solution when it does not have toner particles therein, is a liquid aliphatic hydrocarbon such as Isopar G.

It is important at this point to fully understand the nature of the developed image on the support element which is to be dried. This image is comprised of toner particles of a fusible, resinous, pigmented nature and of a particle size similar to that of toner particles in dry toner mixes commonly used in photocopy machines. Such toner particles can be maintained in suspension in a conventional carrier liquid only by continuous agitation. Upon cessation of the agitation, circulation or turbulence, they readily settle to the bottom. These particles are electrostatically charged and therefore are held by charges to the electrostatically charged image portions of the support element. Some of the carrier liquid in the developing solution is also unavoidably retained on the surfaces of the support element and on the toner particles in the image portions thereof. It assists to some degree in holding the toner particles to each other and to the support element by cohesive or surface tension forces. It is this carrier liquid which is to be removed from the support element, and from the toner particles in the image areas thereof, by means of the method and apparatus of the present invention.

This image, however, is extremely fragile and is disrupted if it is subjected to any undue outside force, which is capable of overcoming the electrostatic attraction and cohesive forces which hold it together. Therefore the drying must necessarily be accomplished without contact of the surface of the support element with mechanical means such as squeegee rolls and the like.

It is important to realize that the visible image may be subjected to close inspection at this point in the process and any deletions of objectionable image portions may be made without destroying the desired image portions. Thus, the image portions to be removed may be physically wiped from the surface of the support element. This is particularly important where the image formed is to be reproduced many times on a printing press and where, therefore, an error in the image could be very costly.

It has been found that when the support element is removed from the rinsing tank, it retains a considerable quantity of liquid on both of its surfaces, some of which will run off of the sheet when it is held in an inclined disposition. Accordingly, the sheet is disposed in a drying chamber in a downwardly inclined position leaving both the front surface and the back surface of the support element substantially exposed to the interior of the drying chamber. In order to accomplish drying in a uniform manner the support element is preferably inverted so that the end thereof which was last to emerge from the rinsing solution is upwardly disposed in the drying chamber. This causes the developing solution and the rinsing solution thereon to drain downwardly over the surfaces of the support element and off the bottom.

It has also been found that warm air or radiantly applied heat tends to lower the viscosity of the developing solution causing it to run more freely. This also allows some of the toner particles to be loosened from image areas and to be distributed over other portions of the surface of the support element which generally comprise the background areas. Obviously, this is highly objectionable as it has a deleterious effect upon image quality. However, by circulating relatively cool air, that is, air at a temperature of less than about 180° F and, preferably, about 115° F, this problem is eliminated and the image areas and toner particles therein remain well defined and intact. Preferably, therefore, such air is sequentially circulated first over the front surface of the support element containing the developed electrostatic image and then over the back surface of the support element to evaporate the volatile portions of the developing or the rinsing solution thereon. The air is emitted near the top of the front surface of the support element as it is disposed in the drying chamber so that it assists in urging excess liquid developing solution downwardly and off the lower end of the support element.

The above-described method of the invention provides a way of drying an electrophotographic support element in a way which does not disturb the fragile powder image contained thereon. In addition, it eliminates the problems associated with providing heat by heated roll or hot air through the chamber, and the tolerances involved in using squeegee rolls, doctors or air knives.

Referring now to the drawings, FIG. **1** shows a combined developing and drying apparatus which incorporates, as a part thereof, an embodiment of the drying apparatus of the present invention, by means of which the method of the invention can be carried out. The developing apparatus includes a developing chamber, indicated generally by reference numeral **10**; a rinsing chamber, indicated generally by reference numeral **11**; and a drying chamber, indicated generally by reference numeral **12**. The developing chamber **10** and apparatus associated therewith is shown in greater detail in FIG. **2**, the rinsing chamber **11** and apparatus associated therewith is shown in greater detail in FIG. **3**, and the drying chamber **12** and apparatus associated therewith is shown in greater detail in FIG. **4**. In each instance the piping or duct work associated with each chamber is schematically illustrated in line form, details of the actual construction necessary to convey the liquid or gas in the indicated places being well within the knowledge of one skilled in the art.

Referring now to FIGS. **1** and **2**, the developing chamber **10** is defined by vertical side walls **13** and **14**, vertical end walls **15** and **16**, and a horizontal bottom wall **17**. A centrally located opening in the bottom wall **17** communicates with a drain **18**. A shallow mixing chamber **20**, defined by the vertical end walls **15** and **16** and side walls **21**, **22** and **13**, is positioned along the top edge of the developing chamber **10** so that developing solution mixed therein flows over the top edge of the side wall **13** and into the developing chamber **10** at a rate sufficient to keep the level of developing solution in chamber **10** at or near the top of the side wall **13**. The two vertical side walls **13** and **14** are closely spaced from one another to provide a narrow vertical developing chamber **10** which is open at the top and in which a support element **23** having a latent electrostatic image on its front surface can be vertically suspended for a sufficient period of time to develop that image in the manner described above. The vertical disposition of the development chamber **10** permits a developing solution to be utilized which contains toner particles having a size and density such that they readily settle in the carrier liquid.

When such a liquid developing solution is introduced in premixed form near the top of the developing chamber **10** as by flowing over the top edge of side wall **13** from the mixing chamber **20**, in which it is agitated or maintained under turbulent conditions to keep the toner particles in temporary suspension, the toner particles slowly settle within the developing chamber **10** while substantially uniformly contacting the surface of the support element **23**. General downward movement of liquid developing solution within the developing chamber **10**, as by a circulating system to be described, also promotes this movement of toner particles past the imaged portions of the support element **23** and ensures greater uniformity of image development. Toner particles passing close to charged image areas are attracted thereto and become electrostatically attached. The concentration of toner particles at any point within the developing chamber **10** adjacent the surface of the support element **23**, however, will be substantially the same, due to the continuous circulation of developing solution therethrough, to ensure uniform development of the image. The side wall **13** of the developing

chamber 10 is electrically connected to ground potential so that it serves as a developing electrode, enhancing the speed and uniformity of image development. The close spacing of the side walls 13 and 14 ensures that a support element in the development chamber 10 will be always close to the side wall 13 which is grounded, preferably with its imaged front surface facing the side wall 13.

The drain 18 is connected by a pipe 24 to a pump 25 which provides a motive force for circulating the developing solution through the developing chamber 10. The pump 25 feeds material through a valve 26 which, when set in one direction, directs the liquid developing solution to a drain 27 as when the developing chamber 10 is to be emptied, and when set in the other position, directs the developing solution through pipes 28 and 30 to a pair of valves 31 and 32, respectively. The valves 31 and 32, in one setting, direct the developing solution through pipes 33 and 34, respectively, to double-ended nozzles 35 and 36, respectively, disposed in the mixing chamber 20 beneath the surface of developing solution therein. The nozzles 35 and 36 are horizontally disposed along the mixing chamber 20 and emit liquid developer in different directions and under considerable force through their ends to create agitation and turbulent flow conditions within the mixing chamber 20 which mixes the toner particles and maintains them in temporary suspension in the carrier liquid. In their other position, the valves 31 and 32 direct liquid developer through pipes 37 and 38, respectively, to opposite ends of an agitator pipe 40 disposed along the bottom wall 17 of the developing chamber 10 beneath the lower end of the electrophotographic support element 23. The agitator pipe 40 has a plurality of openings 41 along its length through which the developing solution is emitted under pressure from the pump 25 to stir up any toner particles which have settled so that they flow toward the drain 18.

Referring now to FIGS. 1 and 3, the rinsing chamber 11 is defined by vertical side walls 42 and 43, vertical end walls 44 and 45, and a horizontal bottom wall 46, which has a centrally located opening therein communicating with a drain 47. The rinsing chamber 11 is also of a size, shape and disposition permitting an electrophotographic support element such as 23 to be vertically disposed therein; that is, the side walls 42 and 43 are closely spaced from one another so as to form a narrow vertical chamber in which large elements can be accommodated and exposed to a rinsing solution without requiring extensive quantities of the rinsing solution. The drain 47 is connected by a pipe 48 to a pump 50 which provides the motive force for recirculating rinsing solution through the rinsing chamber 11. The pump 50 is connected by a pipe 51 to a valve 52 which in one position directs the rinsing solution to a drain 53 when the rinsing chamber 11 is to be emptied, but in the other position directs the rinsing solution through a pipe 54 to a filter 55 from which concentrate in the form of toner particles may be removed through a pipe 56 and filtered rinsing solution may be removed through a pipe 57 which is then fed through two pipes 58 and 60 which connect with openings in the top of each end wall 44 and 45, respectively, of the rinsing chamber 11. Again, the downward flow of the rinsing solution tends to assist excess toner particles, which are dislodged from a support element being rinsed, to quickly settle out from the rinsing solution to the bottom of the rinsing chamber 11 and hence through the drain 47.

Referring now to FIGS. 1 and 4, the drying apparatus of the present invention comprises a drying chamber 12 defined by vertical side walls 14 and 42, end walls 61 and 62, horizontal bottom wall 63 and a hinged top wall 64. The top wall 64 can be opened to the position shown in phantom in FIG. 1 to permit support elements to be inserted into the drying chamber 12 for drying. However, it is closed during the performance of the drying method.

A pair of foraminous support members 65 and 66 are disposed within the drying chamber 12 in a downwardly inclined attitude. The support members 65 and 66 have their lower ends spaced from the bottom wall 63 and the side walls 14 and 42 of the drying chamber 12 and from each other, and their upper ends are attached to the side walls 14 and 42, respectively, of the drying chamber 12. A support element to be dried is disposed upon one of the support members 65 and 66 with its unimaged back surface in contact with the foraminous support member and its imaged front surface directed away from the support member. Each of the support members 65 and 66 has an inwardly depending lip 67 and 68, respectively, at its lower end, upon which the lower end of a support element to be dried rests. The support element and the respective support member upon which it rests divides the drying chamber into two compartments; one behind the support member and one in front of the support member. In this manner, the support element has both surfaces exposed to the atmosphere inside the drying chamber since the support member is foraminous and has many openings therethrough. Some means such as clips (not shown) may be provided to more firmly hold the support element in contact with the foraminous support member.

A feed pipe 70 having a plurality of openings 71 along its length is centrally disposed across the top of the drying chamber 12 and is connected through the end wall 62 by a duct 72 to a fan 73 which feeds air under pressure to the interior of the drying chamber 12 where it is directed toward the surface of the support members 65 and 66. Air removal pipes 74 and 75 are disposed near the upper back portion of each respective support member 65 and 66 between the support member and the respective side walls 14 and 42. The removal pipes 74 and 75 are connected by pipes 76 to a fan 77 which creates a partial vacuum within each of the removal pipes 74 and 75 to assist in creating a flow of air from the inlet opening to the outlet opening of the drying chamber 12. One of the fans 73 or 77 might be omitted as long as the other fan provided a sufficient means for creating a flow of air through the drying chamber 12. Since the support members 65 and 66 are foraminous, that is, since they have a large number of openings 78 over their area permitting one side to communicate with the other, the drying air has sufficient contact with the back surface of the support element disposed thereon to evaporate any residual developing solution contained thereon.

In operation, a support element containing a latent electrostatic image on one of its surfaces, which has

been developed by immersion, first in the developing chamber **10** as described above, and then in the rinsing chamber **11** as described above, is disposed upon one of the support members **65** or **66** with its lower end resting upon the lip **67** or **68**, respectively, at the bottom of the support member **65** or **66** and its imaged surface directed away from the foraminous support member. The hinged top wall **64** to the drying chamber **12** is then closed to confine the support element within the drying chamber **12**. Air is then admitted to the central compartment of the drying chamber **11**, and directed over the front surface of the support element starting near the top thereof as it is disposed in the drying chamber **12**. The air is directed from ports or openings **71** in the feed pipe **70** in a direction preferably downwardly over the front surface of the support element, causing volatile components in the liquid developing solution thereon to evaporate. Downward movement of the drying air is also generally promoted throughout that compartment of the drying chamber **12** by means of either the fan **73**, or the fan **77**, or both. The air passes beneath the lower end of the support element and then flows upwardly along the back surface of the foraminous member **65** or **66** and in at least partial contact with the back surface of the support element thereon by means of the openings **78** in the foraminous member **65** or **66**. This promotes evaporation of volatile components of the liquid developing solution from the back of the support element to dry it. The air and volatilized components of the rinsing and developing solutions are then withdrawn from that compartment of the drying chamber **12** near the top of the backside of the foraminous member by the respective removal pipe **74** or **75** which leads to the fan **77**.

From the above description of the invention and of the drawings, it can be seen that the invention provides a novel method and apparatus for drying an electrophotographic support element containing on its front surface a latent electrostatic image which has been developed in a liquid medium. In particular, it is apparent from the above description that the drying apparatus and method enables a support element to be dried without disturbing the image formed by the toner particles thereon in a way which would cause streaking or loss of resolution. It is also apparent that the method and apparatus can be used to dry images having a greater quantity of toner material thereon, such as one formed by toner particles having a larger particle size. Such an image results in a more permanent image area which will withstand the forces which are experienced on a printing press.

From the above description of the invention, it is apparent that various modifications in the apparatus described in detail herein may be made within the scope of the invention. For example, many successive foraminous support members may be employed to accommodate a large number of support elements. It should also be clear that the precise temperature of the air used for drying is not critical. In addition, the form of the support elements might vary quite slightly, as from a woven wire structure to a perforated plate, for example. Therefore, the invention is not to be limited to the specific details of the method and apparatus described herein, except as may be required by the following claims.

What is claimed is:

1. Apparatus for drying an electrophotographic support element containing on its front surface a latent electrostatic image which has been toned and rendered visible by immersion of said support element in a developing solution comprising a mixture of charged toner particles in a carrier liquid, comprising

wall means defining a drying chamber,

air pervious means for supporting said support element in a downwardly inclined position in said drying chamber so as to divide said drying chamber into at least two compartments with at least one end of said support element being spaced from said wall means to leave a communicating passageway between said two compartments, said air pervious means being adapted to support said support element so as to permit contact of air with both surfaces of said support element,

air inlet means and air outlet means disposed on opposite sides of said support element when supported by said air pervious means and arranged so that the air will pass from said air inlet means across one entire surface of said support element, through said communicating passageway, across the opposite surface of said support element in reverse direction, and through the air outlet means, and

circulating means for creating a flow of air from said air inlet means to said air outlet means through said drying chamber.

2. Apparatus according to claim **1**, wherein said air pervious means comprise a foraminous member upon which said support element is disposed so that its back surface contacts said foraminous member and said front surface is directed away from said foraminous member.

3. Apparatus according to claim **1**, wherein said support element when supported by said air pervious means is spaced from the wall means defining the bottom of said drying chamber to form said communicating passageway between said two compartments.

4. Apparatus according to claim **1**, wherein said air inlet means emits air adjacent said front surface of said support element, and said air outlet means removes air from adjacent the back surface of said support element.

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