

Jan. 8, 1957

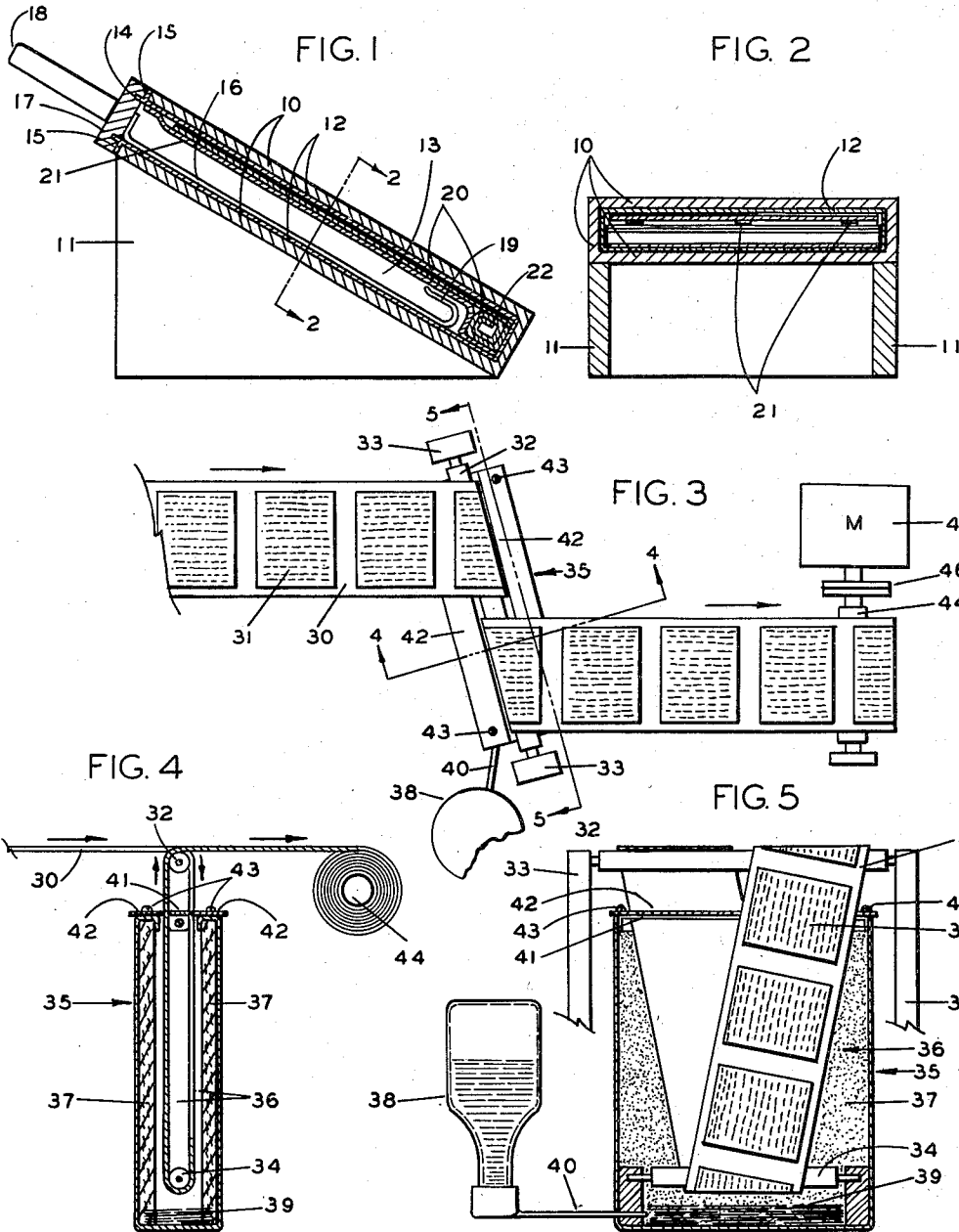
C. F. CARLSON

2,776,907

METHOD OF FIXING ELECTROSTATIC POWDER IMAGE

Filed July 18, 1952

3 Sheets-Sheet 1



Jan. 8, 1957

C. F. CARLSON

2,776,907

METHOD OF FIXING ELECTROSTATIC POWDER IMAGE

Filed July 18, 1952

3 Sheets-Sheet 2

FIG. 6

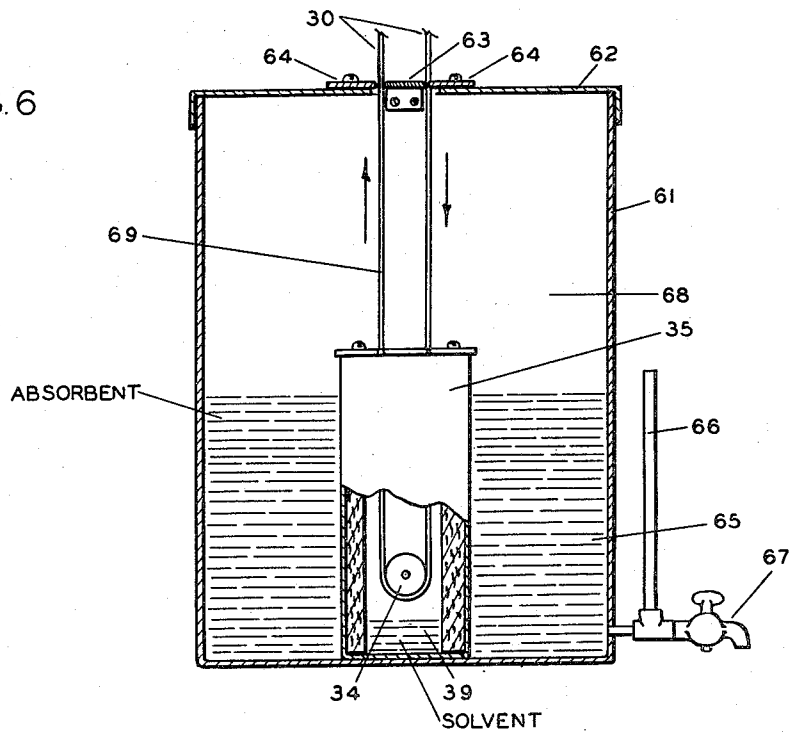
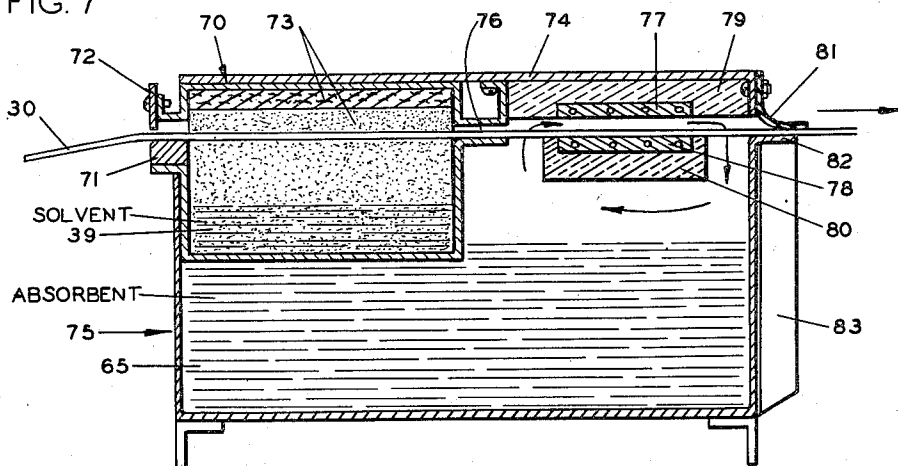


FIG. 7



INVENTOR

Chester F. Carlson

Jan. 8, 1957

C. F. CARLSON

2,776,907

METHOD OF FIXING ELECTROSTATIC POWDER IMAGE

Filed July 18, 1952

3 Sheets-Sheet 3

FIG. 8

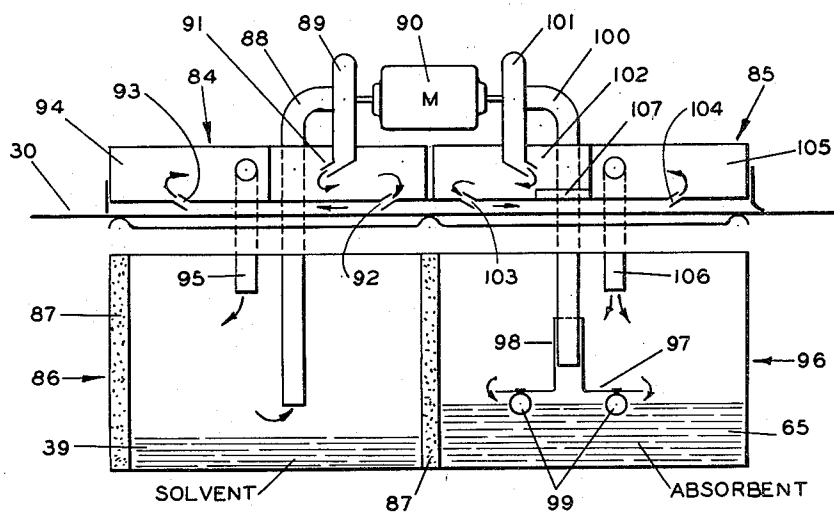
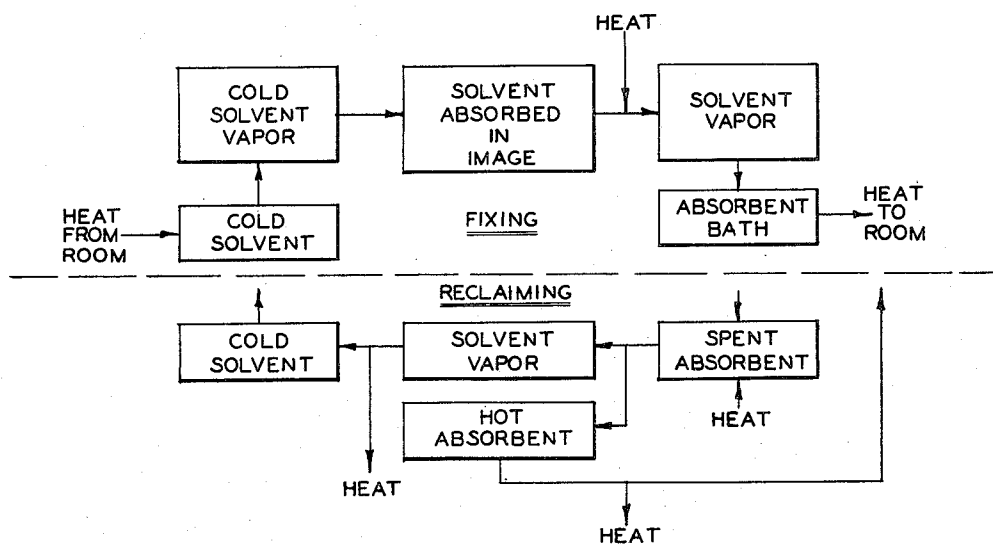


FIG. 9



INVENTOR

Chester F. Carlson

1

2,776,907

METHOD OF FIXING ELECTROSTATIC POWDER IMAGE

Chester F. Carlson, Pittsford, N. Y., assignor to The Battelle Development Corporation, Columbus, Ohio, a corporation of Delaware

Application July 18, 1952, Serial No. 299,673

6 Claims. (Cl. 117—17.5)

This invention relates to image fixing methods, particularly methods of fixing powder images.

The present application is a continuation-in-part of co-pending application, Serial No. 157,883, filed April 25, 1950.

In certain electrostatic recording processes, such as the electrophotographic, xerographic and electric printing processes described in my Patents 2,221,776; 2,297,691 and 2,357,809, and the process of graphic recording described in my application Serial No. 558,252, filed October 11, 1944, now Patent 2,624,652, an electrostatic image is developed by depositing a powder on a surface to produce a powder image. The powder image is then affixed to the surface upon which it has been deposited or on another surface to which it has been transferred. Heretofore, the usual method of fixing has been by the process of heat fusing, in which case the powder image must be formed of a thermo-adhesive material, such as a fusible resin, which becomes adhesive when heated.

While heat fusing has been put to practical use, certain difficulties have been encountered. Where the image is to be fused to paper or other organic base, as is usually the case, the powder must be made of material which becomes adhesive at a temperature below that which will cause damage to the organic base. This imposes limitations on the choice of resins which make it difficult to meet other desirable characteristics in the powder composition. Moreover, it has been difficult to reach an entirely satisfactory design of heat fuser with regard to short warm-up time, low electric current requirements, adequate heat insulation and uniform heat distribution.

Fixing of powder images by condensing a liquid solvent onto the image surface from a heated solvent vapor, as described, for example, in my above-mentioned applications Serial No. 558,252 and 157,883, has been successfully used and offers the advantages of a broadened choice of powder materials, lower power requirements, and elimination of heat damage to the base sheet.

The present invention contemplates a further improvement in solvent vapor fixing of powder images which eliminates all or most electric power requirements, simplifies the design of equipment, materially reduces the consumption of solvent and the loss of solvent vapor, and eliminates all delays due to warm-up time. This is accomplished by methods and apparatus which introduce the powder image into an atmosphere of solvent vapor which is at substantially the same temperature as the powder image, or even at a lower temperature than the image. The vapor atmosphere is held at a vapor concentration sufficient to produce absorption of solvent vapor by the powder image and consequent fusing of the image, but there is no thermal condensation on the paper or other base which supports the powder image. The base material consequently remains dry.

Other features of the invention will be brought out and exemplified in the disclosure hereinafter set forth, including the illustrations in the drawings.

2

In the drawings:

Figure 1 illustrates a manually operated cold vapor fixing device for fixing powder images onto sheet materials by the method of the present invention;

Figure 2 is a section on the line 2—2 of Figure 1;

Figure 3 is a top view of a vapor fixing device for an electrostatic powder printing or xerographic copying machine, and a web of paper carrying powder images in the process of being fixed by the device;

Figure 4 is a section on the line 4—4 of Figure 3;

Figure 5 is a section on the line 5—5 of Figure 3;

Figure 6 illustrates a modification in which a solvent absorbent chamber is added, the section being similar to that of Figure 4;

Figure 7 shows a form of vapor fuser and solvent absorption unit for straight-through operation;

Figure 8 is a diagram of a fuser-absorber for high production speeds; and

Figure 9 is a diagram of the process steps which can be used with the apparatus of Figures 6, 7 and 8.

The vapor fixing device of Figures 1 and 2 is a hand operated unit which may be used for fixing powder images onto individual sheets of paper, cloth, metal, plastic or the like, and even onto the surfaces of electrophotographic plates. It comprises a wooden box or housing forming a wide flat and deep enclosure having its mouth or entrance at one end. A pair of triangular legs support the housing at an incline of about 30 degrees with the horizontal supporting surface, the mouth forming a horizontal opening at the upper front end.

The housing 10 is lined with a sheet metal lining 12 which is welded or soldered to provide a liquid-tight vapor chamber 13. The open end of lining 12 projects a short distance out of the mouth of wood housing 10, as shown at 14, the sheet metal being doubled back and bent out to provide flanges 15 which fit against the end of the wood housing and which may be attached to the wood housing. A slide member 16 of sheet metal is arranged to be moved into and out of vapor chamber 13 by its wooden end piece 17 which is provided with a handle 18. End piece 17 is provided with a groove which fits over the projecting edges 14 of the lining 12, so that when the slide is inserted in the chamber the block 17 provides a tight closure for the vapor chamber. Slide 16 rests flat against the sloping lower wall of the chamber and is turned up and back at its inner end to provide a channel portion 19 in which the lower end of a copy sheet carrying a powder image may be inserted for positioning and support during fixing.

A solvent wick 20 formed of felt, cloth or blotting paper is supported against the sloping ceiling of the vapor chamber 13 by a series of stiff sheet metal ribs 21 which are secured at their outer ends to the ceiling near the mouth of the chamber and extend along close to the ceiling and then bend down to form feet which rest on the bottom and bear against the rear end of the chamber. The lower end of wick 20 is rolled into a wad 22 at the bottom of the chamber.

The fixing device is prepared for operation by pouring a quantity of a liquid solvent into the chamber sufficient to saturate the wick 20. The slide is inserted so that the end piece 17 closes the chamber and the device is allowed to stand until the solvent is drawn up along the ceiling of the chamber by the wick and the vapor space 13 becomes saturated with solvent vapor. The choice of solvent will depend upon the composition of the powder images to be fixed. With powders formed of pigmented rosin, copal, asphalt and other natural resins as well as several synthetic resins and plastics, such as ethyl cellulose, a desirable solvent is trichloroethylene. Amyl acetate or butyl acetate can likewise

3

be used with many resins. Butyl alcohol and perchloroethylene are also useful, particularly in hot weather, as they are somewhat less volatile.

Powder images can be fused in the device as soon as a saturated vapor atmosphere has been generated. Once the wick has become wet with solvent over its entire area the necessary vapor atmosphere is quickly produced. The operator can then fix copies by simply grasping handle 18, withdrawing slide 16, placing a sheet bearing a powder image on the slide, inserting the slide in the chamber 13 for a few seconds, withdrawing the slide and removing the copy.

Although the solvent and solvent vapor are at the same temperature as the copy sheet and powder image, namely, at room temperature, fusion of the image takes place, provided the powder is soluble in the solvent. The powder absorbs solvent from the vapor phase until it becomes adhesive. In some instances the powder image will absorb enough solvent to completely liquify it. It has been found, however, that serious spreading of the image does not take place on paper base material unless the copy is allowed to remain in the fixing device much longer than the few seconds needed for fusing. The fusing time is not critical, whereas it is with heat fusing.

As soon as the fused copy is removed from the vapor chamber the solvent begins to evaporate from the image and the image solidifies and becomes permanently bonded or fixed onto the base material in a few seconds.

Since the solvent vapor has a density greater than that of air it tends to remain in the vapor space 13 as the slide is removed and reinserted. The small loss of vapor due to absorption by the powder image and drag-out by the slide is quickly regenerated from the wick 20 so that copies can be fused in rapid succession. On the other hand, when not in demand, the device stands ready for use at any moment since the vapor atmosphere is maintained in the space 13 at all times. Recharging with solvent is necessary only at infrequent intervals and with moderate use one charge of a few cubic centimeters of liquid solvent may last several days.

This method of operation, in which the vapor is at the same temperature as the copy, is much more economical of solvent than vapor fixing methods in which the solvent is heated, as with cold vapor there is no condensation on the paper base unless it carries a resin or material soluble in the solvent used. In most cases the powder image is the only part of the copy which absorbs the solvent and its requirements are very small. With unheated solvent the loss due to vapor leakage from openings in the vapor space is practically negligible since the vapor is kept denser than air and no vapor pressure is built up to drive solvent out of the chamber.

The advantages of the present invention are most fully realized in the fixing of powder images to paper using the vapor of a non-aqueous solvent such as the organic solvents and chlorinated organic solvents, where the economy of solvent consumption is an important factor, and the evaporation of excessive quantities of solvent into the room may be objectionable. Moreover, these solvent vapors at the same temperature as the copy to be fixed are not noticeably absorbed by the paper base and do not produce any dimensional change or buckling in the base.

Aqueous solvents are not useful, of course, in fixing most resin or plastic images as these materials are not water-soluble. Where water-soluble image forming materials are used, some spreading and loss of sharpness may frequently take place due to the humidification of the cellulose fibres of the paper during fusing.

For effective fusing of a powder image to take place the solvent vapor is held at a great enough concentration in the vapor fixing chamber to produce absorption of solvent vapor by the powder until the powder becomes adhesive. This means that the partial pressure of the solvent vapor shall exceed the vapor pressure of a solu-

4

tion of the powder (or the soluble constituents of the powder) which contains sufficient absorbed solvent to be adhesive. A concentrated vapor atmosphere is insured by providing a reservoir of liquid solvent in contact with the vapor space, particularly if the solvent is brought to the upper part of the vapor space by a wick or other means so that the higher density vapor will settle and fill the space. The air in the chamber is thus saturated with vapor, and the concentration is maintained in excess of the minimum requirements even with frequent use.

While the advantages of the process are greatest where base materials, such as paper, which are not soluble in the solvent are used, the method may sometimes be used to affix powder images to plastic films and to plastic coated paper, in which the plastic may be made adhesive by the solvent and the powder may or may not be affected by the solvent. In the case of films, the fusing time must, of course, be controlled to obtain only a surface adhesion without undue softening the entire plastic layer.

Figures 3, 4 and 5 show a vapor fixing device for fusing a continuous web of copy issuing from an electrostatic powder printing machine or a continuous electrophotographic copying machine. Paper web 30 carrying the unfixed powder images 31 enters in a horizontal plane from a powder printing or copying machine located at the left, as viewed in Figures 3 and 4, and passes over a horizontal roller 32 mounted in bearings on supports 33 and extending obliquely or diagonally across the web. The web then passes obliquely downward for a substantial distance to a point where it passes around and under a horizontal roller 34 mounted in bearings parallel to roller 32 and directly beneath it. The web then passes diagonally upward and around and over roller 32 again, this time at a spaced position on the length of roller 32 as clearly seen in the drawings, from which point it passes to a take-up reel 44 driven by motor 45 through constant tension clutch 46. It will be noted that the powder images are always kept on the outside of the web as it passes around rollers 32 and 34 so that no surface is brought into contact with the images.

A vapor tank 35 encloses roller 34 and the major part of the web between rollers 32 and 34. The tank provides a saturated vapor space 36 which is lined with a porous wicking of fibreboard, fabric or blotting paper and a solvent fountain bottle 37 maintains a shallow layer of liquid solvent 39 in the bottom of the tank by supply tube 40 to keep the wicking saturated.

The top of the tank is closed in part by a central guide bar or plate 41 which is in contact with the inside face of the web entering and leaving the tank. A pair of adjustable plates 42 are mounted along the upper edges of the tank by screws 43 so that the inner edges of these plates can be adjusted to keep the entering and leaving slots at the minimum necessary to avoid contact with the image and still prevent excessive drag-out of vapor.

In operation of the fusing device of Figures 3, 4 and 5 the web 30 carrying the powder images is drawn through the device by the take-up reel 44, the web being kept under tension by the take-up reel and by a braking member on the supply reel in the printing or copying machine. As the web enters the vapor space 36 the powder image absorbs solvent vapor and becomes adhesive.

When the web emerges the absorbed solvent rapidly evaporates and the images reach the take-up reel in dry condition. For high production machines a ventilating system may be provided to remove vapor from the room.

Since substantially the only solvent consumed is that carried out of the tank by the resin image the fuser is very economical of solvent consumption and very little vapor is released into the room. An average powder image of text matter contains about one-twentieth of a gram or less of resin powder per square foot and an equal weight of solvent is sufficient to cause fusion. It is obvious that the rate of solvent consumption, using cold

5

vapor fusing, is very low. This has a marked advantage over heated vapor systems in which substantial quantities of solvent condense onto the entire web, whether an image is present or not, and must again be evaporated from the web. The evaporation of solvent from the liquid phase at a rate sufficient to maintain vapor saturation in space 36 can readily be provided by the conduction of heat inward through the chamber walls from the room. Evaporation of solvent into the vapor space lowers the temperature of the walls one or two degrees below room temperature causing the walls to absorb heat from the air around the tank.

Figure 6 shows a modification applicable to the apparatus of Figures 3, 4 and 5 which provides the added feature of capture and absorption of solvent evaporated from the fused images. In this embodiment the fusing tank 35 is enclosed in an absorption tank 61 through which the web passes on entering and leaving tank 35. Absorption tank 61 is provided with a removable cover 62 having a web opening provided with a guide bar 63 and side plates 64 similar to those in the top of the fusing tank. A liquid absorbent 65 fills the space in tank 61 around the sides of inner tank 35 and an overflow pipe 66 and drain valve 67 are provided and tapped into the side of absorbent tank 61 near its bottom. The open end of overflow pipe 66 is below the level of the top of inner tank 35 and insures that the absorbent liquid will not rise to a height where it can flow into the inner tank.

An absorbent liquid 65 is used which itself has low vapor pressure and which will readily absorb or dissolve large quantities of the solvent vapor used in inner tank 35 before the solvent vapor pressure from the mixture rises to a very high value. Thus, when trichloroethylene is used as a fusing solvent, the absorbent may be a high boiling petroleum fraction such as paraffin oil, new or used lubricating oils, and even oils containing a high percentage of dissolved waxes or tars, or crude petroleum with the volatile fractions removed. Suitable absorbent liquids for the volatile esters and alcohols include the higher boiling esters, alcohols, aliphatic oils, and some hydrocarbons.

In operation of Figure 6 the vapors space inside tank 35 is kept saturated with solvent vapor as previously described, while the space 68 above the absorbent liquid in outer tank 61 contains air in which the solvent vapor concentration is kept very low by the absorbent. As the web passes through inner tank 35 the powder images are fused with solvent vapor as previously described. Then as the ascending portion 69 of the web passes through air space 68 the solvent evaporates from the images so that they leave tank 61 in substantially dry and fixed condition. The solvent vapor released into space 68 is rapidly absorbed by the absorbent liquid 65 thus keeping the vapor pressure of solvent in space 68 at a very low value which is most effective for drying the images. Absorption of solvent vapor by liquid 65 will gradually increase its volume and the liquid level will rise in the outer tank. Should the level accidentally exceed the height of standpipe 66 the liquid will overflow through the pipe and prevent further rise of the level which might flood liquid over into inner tank 35. As solvent vapor is absorbed the concentration of dissolved solvent in the absorbent liquid 65 increases and consequently the vapor pressure of solvent in space 68 will gradually rise and decrease the thoroughness of the evaporation from the images. When the effectiveness of the absorbent liquid has been lowered to the point where adequate drying of the images no longer occurs it is replaced with fresh absorbent.

Figure 7 illustrates another fixing device in which the web 30 is fed straight through in a horizontal plane. The web enters fusing tank 70 through a horizontal slot defined by guide bar 71 and adjustable plate 72 and is provided with solvent vapor by solvent liquid 39 and

6

wick member 73 inside the tank. Solvent tank 70 is mounted inside the cover 74 of rectangular absorbent tank 75 and as the web 30 leaves the solvent tank it passes through a long shallow slot 76 into the air space above absorbent liquid. Here the web passes between a pair of closely spaced horizontal electric hotplates or strip heaters 77 and 78 surrounded by layers of insulation 79 and 80 on all sides except the shallow space between them through which the paper web passes. The web and the fused images it carries are heated slightly by these plates to drive off the solvent more rapidly. The travel of the web sets up a circulation of air in the absorption chamber, as indicated by the arrows, which carries the slightly warm solvent vapor driven off from the web down over the surface of the absorbent liquid which rapidly takes up the solvent. The web leaves the absorption tank through an air seal comprising a soft rubber flap 81 which slides on the top surface of the web as the web rides over the horizontal guide flange 82 on leaving the tank. Tank 75 may be provided with cooling fins, such as 83, to keep the absorbent liquid near to room temperature. Most of the heat generated by the hotplates is carried out by the paper web.

Figure 8 shows another form of straight-through fixing device especially suitable for high production speeds. As the web 30 passes horizontally from left to right, as shown, it passes first under a fusing head 84 where solvent vapor is blown against and along the web, and then the web passes under a drying head 85 where drying air is blown along its surface. Solvent vapor is generated in tank 86 containing liquid solvent 39 and having wicks 87 lining its walls. The vapor is drawn from the lower part of the vapor space through conduit 88 to the intake opening of blower 89 driven by electric motor 90. The output of the blower passes into a chamber 91 of the head 84 from which chamber it emerges through sloping slot 92 which projects the vapor stream against the top of the web 30. The vapor stream passes along the web to return slot 93 through which it passes into a chamber 94 and then through conduit 95 back to the top of tank 86. By providing a forced circulation of vapor the fusing process is accelerated.

A similar system is provided for circulating drying air from absorption tank 96 through drying head 85. Air from the upper part of tank 96 is drawn under the horizontal flange 97 of floating intake nozzle 98 which is supported on floats 99 in order to route the air close to the surface of the absorbent liquid 65. The air passes up through conduit 100 to the intake part of blower 101 driven by motor 90. From the blower the air enters chamber 102 in head 85, then passes out of slot 103 and against the web, then along the web, through slot 104, chamber 105 and conduit 106 back to tank 96. A heater 107 mounted above the web in the air passage may be energized if desired to heat the web and hasten evaporation during drying.

Figure 9 is a diagram of a process cycle which may be used with Figures 6, 7 and 8, and an optional reclaiming cycle in which the solvent and absorbent are reclaimed by distillation of the spent absorbent bath. Where it is uneconomic to reclaim the materials the distillation steps can be eliminated and the spent absorbent liquid is thrown away. The heat introduced in the generation of the cold vapor is preferably obtained from the surroundings and is sufficient only for vaporization of the solvent to produce a vapor at room temperature. The heat introduced in drying the web may come from the drying air at room temperature or may be supplied in part by an electric heater as described in connection with Figures 7 and 8. The temperature of the absorbent bath is raised slightly during operation and the heat passes out through the tank walls into the room, aided, if necessary, by added cooling surfaces on the tank in order that the bath temperature shall be held as low as possible.

7

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

What is claimed is:

1. In a process wherein an electrostatic image corresponding to a pattern of light and shadow to be reproduced is made visible by depositing powder on a surface in conformity with said electrostatic image and affixing said powder in image conformation to a support material, the improvement comprising affixing said powder in image conformation by introducing said support material into the vapor of an organic liquid solvent for an adhesive constituent of at least one of the materials from which said powder image and said support material are formed, said vapor and said support material being at ambient temperature and said vapor being at a partial pressure exceeding the vapor pressure of solvent from a tacky solution of said adhesive constituent, and then removing said support material from said vapor after said adhesive has become tacky, and removing said solvent from said adhesive to permanently bond said image to said support material.

2. The method of claim 1 in which said powder image is formed of a pigmented resin and said solvent is a solvent for said resin.

3. In a process wherein an electrostatic image corresponding to a pattern of light and shadow to be reproduced is made visible by depositing resin powder on a surface in conformity with said electrostatic image and affixing said powder in image conformation to paper, the improvement comprising affixing said powder in image conformation by introducing said paper surface carrying said powder image into a chamber containing the vapor of a volatile solvent for said resin, said paper, powder image and vapor all being at ambient temperature, and then after said resin-base powder has become adhesive through absorption of solvent removing said paper and image from said chamber to permit evaporation of solvent whereby said resin-base image becomes permanently bonded to said paper surface.

4. The method of claim 3 in which said resin powder

8

is insoluble in water and said solvent is an organic solvent in which said resin becomes tacky.

5. The method of claim 3 in which said resin-base powder is formed of a resin and a pigment suspended therein, and said solvent is an organic solvent in which said resin is soluble.

6. In a process wherein an electrostatic image corresponding to a pattern of light and shadow to be reproduced is made visible by depositing dry colored resin powder onto the surface of a sheet upon which it is loosely supported in conformity with said electrostatic image and affixing said powder in image conformation to said sheet, the improvement comprising introducing said sheet and powder image into an enclosed space containing the vapor of a solvent for said resin, said vapor and said sheet being at ambient temperature and said vapor being at a partial pressure exceeding the solvent vapor pressure of a tacky solution of said resin therein to tackify said resin powder whereby said image is permanently affixed to said sheet without impairing the resolution and clarity of said image and then, transferring said sheet with the tacky image into an air space in which the solvent vapor pressure is below the solvent vapor pressure of a tacky solution of said resin, to evaporate solvent from said resin solution and leave the resin image affixed to said surface.

References Cited in the file of this patent

UNITED STATES PATENTS

921,229	Gleason	May 11, 1909
1,141,224	Wawrziniok	June 1, 1915
1,339,529	Verhoogen	May 11, 1920
1,569,048	Stock	Jan. 12, 1926
1,811,107	Barnebey	June 23, 1931
2,034,008	Taylor	Mar. 17, 1936
2,097,885	Koppe	Nov. 2, 1937
2,138,578	Hershberger	Nov. 29, 1938
2,221,776	Carlson	Nov. 19, 1940
2,250,925	Babcock	July 29, 1941
2,297,691	Carlson	Oct. 6, 1942
2,361,350	Keep et al.	Oct. 24, 1944

FOREIGN PATENTS

7,402	Great Britain	of 1906
-------	---------------	---------