Nov. 29, 1966 H. E. CLARK 3,288,624

VAPOR FUSING METHOD FOR XEROGRAPHIC POWDER IMAGES

Original Filed Aug. 15, 1962 2 Sheets-Sheet 1

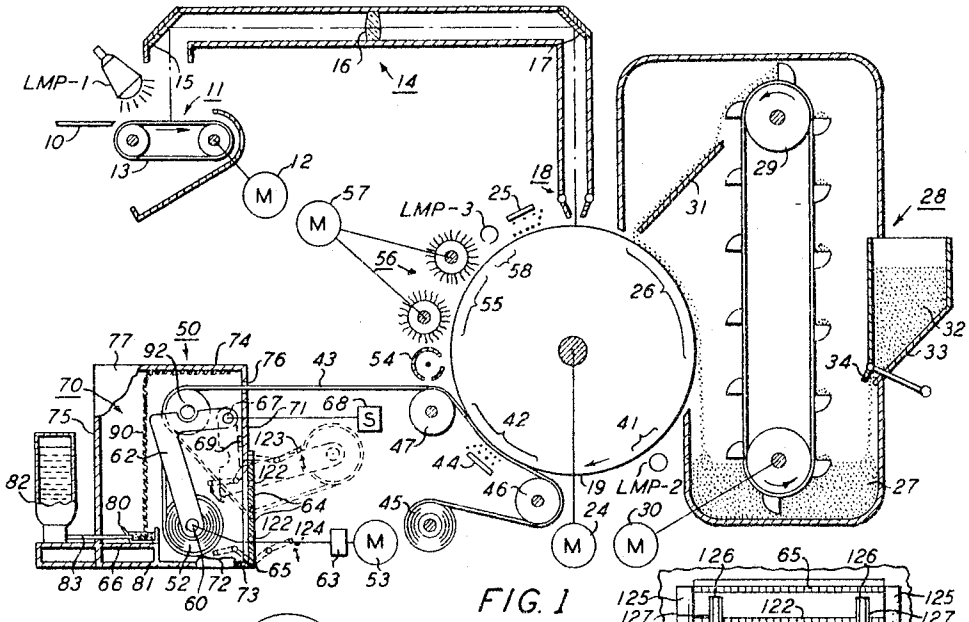



FIG. 1

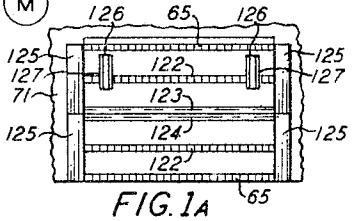


FIG. 1A

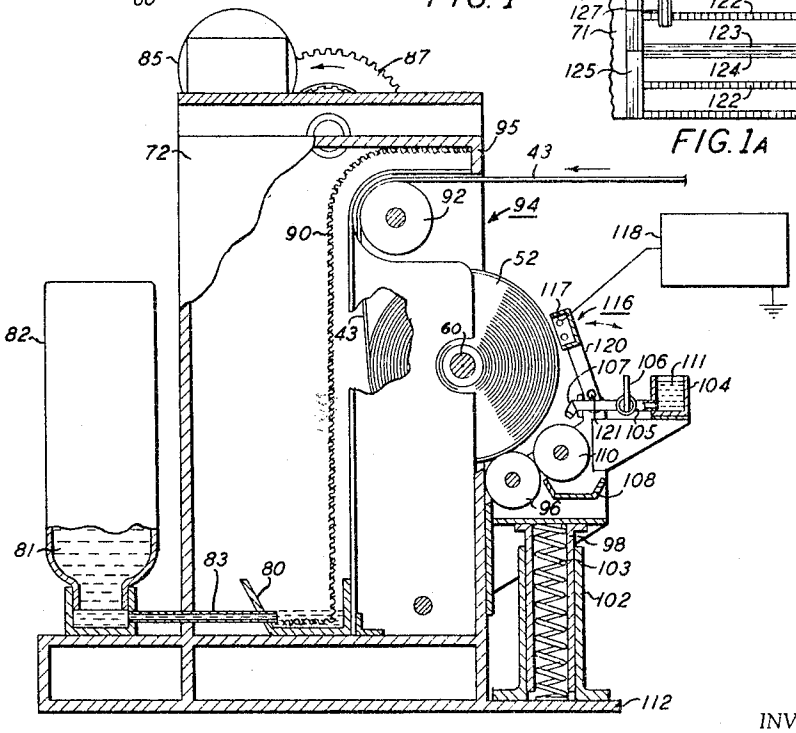


FIG. 3

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VAPOR FUSING METHOD FOR XEROGRAPHIC POWDER IMAGES

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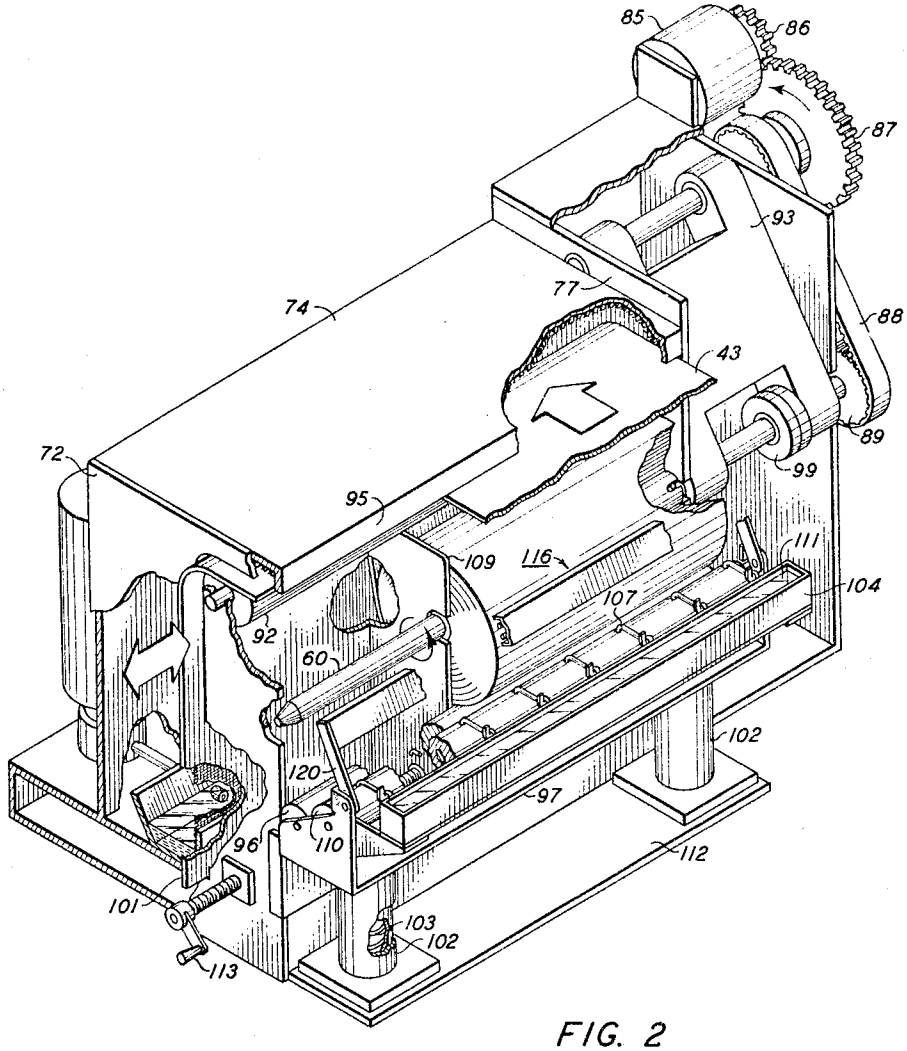



FIG. 2

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3,288,624

# VAPOR FUSING METHOD FOR XEROGRAPHIC POWDER IMAGES

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Original application Aug. 15, 1962, Ser. No. 217,027, now Patent No. 3,215,116. Divided and this application June 1, 1965, Ser. No. 467,803
4 Claims. (Cl. 117—21)

This application is a division of application Ser. No. 217,027, filed Aug. 15, 1962, now U.S. Patent 3,215,116.

This invention relates to improved apparatus for fusing powder images onto the surface of support material. More particularly, the invention relates to xerography and to method and apparatus for vapor fusing of powder images loosely formed xerographically onto a continuous support web.

In the process of xerography, as first disclosed, for example, in Carlson Patent U.S. 2,297,691, a previously formed electrostatic latent image on the surface of a xerographic plate is rendered visible by developing with a powder deposited on the plate surface. Commercial forms of powder used for developing are usually of a pigmented resin such as disclosed in Rheinfrank et al. patent U.S. 2,788,288 and Carlson patent U.S. Reissue 25,136. The powder image thus formed is then affixed to the surface upon which it has been deposited or onto the surface of another support material to which it may have been transferred by techniques known to those skilled in the art.

Conventionally there are two usual methods by which a powder image is affixed. The first of these methods is with the application of heat in which case the powder image or its support must be formed of a thermo-responsive material, such as a heat fusible resin, which flows without image distortion when heated and coalesces when cooled to ambient temperature. The second of these methods is to introduce the image-bearing support material into an atmosphere of the vapor of a solvent for the developing powder as disclosed in Carlson patent U.S. 2,776,907. In the solvent vapor process, the powder image is rendered a tacky cohesive mass while in the presence of the atmosphere of the solvent vapor and usually while still tacky is removed to ambient air for evaporation of the solvent, leaving the image bonded to the support member. The solvent vapor process is referred to in the art as "vapor fixing."

While heat fusing has been put to wide scale commercial use in automatic machines, it is recognized that improvements are possible. For example, most commercially marketed machines employ a thin layer of vitreous selenium as the photoconductor. Continuous heat exposure is known to have a deleterious effect on the photoconductive properties of selenium. Dissipation or insulating of the heat, therefore, must be carefully controlled. When the image is to be fused to paper, cellulose acetate, or other base having a relatively low charring or combustion temperature, 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 base. This imposes limitations on the choice of resins which make it difficult to meet other desirable characteristics in the powder composition. Furthermore, certain paper stocks, such as used in record controlled accounting cards, have controlled moisture contents which are decreased at high temperature destroying cards for



their intended purpose. Moreover, it has become difficult to reach an entirely satisfactory design of heat fuser with regard to a short warm-up time, low electric current requirements, adequate heat insulating and uniform heat distribution particularly at high operating speeds without the attendant disadvantage of fire hazard associated with fusers employing heat as the fusing media.

Vapor fixing of powder images by means of a solvent vapor has also been put to a practical use and found to form dense, blacker images than formed by heat fusing. However, most solvents suitable for use in conjunction with these resins generally used in toners are characterized by various orders of undesirability such as obnoxious odor, toxicity, etc. For example, one such solvent found particularly suited for fusing xerographic images is trichloroethylene, which happens to be characterized by objectional odor and a degree of toxicity which can raise to an objectionable level if allowed to escape to the room at a high rate.

Operation of vapor fusing devices heretofore has included removal or emergence of the image-bearing support surface from the vapor chamber such that the support surface contained not only absorbed vapor but also was accompanied by "vapor dragout," i.e., a layer of solvent vapor accompanying the moving support surface. This dragout not only has contributed to the inefficiency of the system but its effect on air dilution has caused general uncomfortableness for the operators of the apparatus in attendance not to mention the inherent toxic dangers. Where there is likely to be large volumes of copy to be fused, as is usual with automatic xerographic machines operated continuously, expensive and bulky ventilation equipment has been required to avoid atmospheric contamination.

Apparatus, therefore, employing trichloroethylene as a fusing solvent, and vapor fusing in general has encountered restricted and intermittent use and has generally been employed only on low volume output equipment.

Now in accordance with the instant invention, there is provided improved method and apparatus employing solvent vapor for continuous fusing operation particularly suited for automatic xerographic apparatus with continuous web support members and adapted for high speed operation.

It is, therefore, an object of the invention to provide novel method and apparatus for vapor fixing of powder images onto surfaces of continuous support material on which the powder image is loosely supported.

It is a further object of the invention to provide improved vapor fixing apparatus for continuous fixing of the xerographic powder images to moving support material.

It is a further object of the invention to achieve vapor fixing of xerographic powder images onto a continuous support web by improved apparatus resulting in substantially reduced solvent consumption and vapor dragout as compared to other such devices of the prior art.

It is a further object of the invention to provide novel vapor fusing apparatus for a continuous web in which vapor dragout to ambient atmosphere is substantially eliminated.

These and other objects will appear clearly in the following specification when read in connection with the drawings, the novel features being pointed out in the claims at the end of the specification.

In the drawings:

FIG. 1 is a schematic arrangement of an automatic xerographic apparatus incorporating one embodiment of the fuser apparatus of the invention;

FIG. 1*a* is a front view of the door mechanism of FIG. 1;

FIG. 2 is an isometric view of a second embodiment of fusing apparatus in accordance with the invention; and,

FIG. 3 is a sectional elevation through the embodiment illustrated in FIG. 2.

For a general understanding of the xerographic processing system by which the invention is being illustrated, reference is had to FIG. 1 in which the various system components are schematically illustrated. As in most xerographic systems based on the concept disclosed in the above-cited Carlson patent, a light radiation image of copy to be reproduced is projected onto the sensitized surface of a xerographic plate to form an electrostatic latent image. Thereafter, the latent image is usually developed with oppositely charged developing material to form a xerographic powder image, corresponding to the latent image, on the plate surface. In one common system of the reusable type, i.e., one in which the xerographic plate is recycled, the powder image is then generally electrostatically transferred to a support surface to which it is usually fused by a fusing device causing the image to permanently adhere to the support surface.

In another well known type of system utilizing an expandable type plate as, for example, a commercially marketed plate of zinc oxide in a suitable binder on a flexible support, the powder image is formed and fused directly thereon. Therefore, for purposes of illustration, the invention will be described in connection with the reusable type of xerographic plate in which the transferred image is to be fused to a secondary support surface. It is to be understood, however, that the fusing apparatus of the invention has utility with any form of web surface on which the image is contained including the expendable type xerographic plate.

The xerographic apparatus described herein typically may be of the type disclosed in copending application, Ser. No. 837,173, filed Aug. 31, 1959, in the names of A. J. Cerasani et al., now patent U.S. 3,076,392. Opaque copy to be reproduced is placed on a support tray **10** from which it is fed onto a transport mechanism generally designated **11**. Suitable drive means are provided for the transport mechanism from motor **12** to endless belts **13** whereby copy is moved past the optical axis of projection lens system **14** and illuminated by a projection lamp LMP–1. The image of the copy is reflected by mirror **15** through an adjustable objective lens **16** and then reflected by mirror **17** downwardly through a variable slit aperture assembly **18** and onto the surface of a xerographic plate in the form of drum **19**.

Xerographic drum **19** includes a cylindrical member mounted in suitable bearings in the frame of the machine and is driven in a clockwise direction by a motor **24** at a constant rate that is proportional to the transport rate of the copy, whereby the peripheral rate of the drum surface is identical to the rate of movement of the reflected light image. The drum surface comprises a layer of photoconductive material on a conductive backing that is sensitized prior to exposure by means of a corona generating device **25** energized from a suitable high potential source.

The exposure of the drum to the light image discharges the photoconductive layer in the areas struck by light, whereby there remains on the drum a latent electrostatic image in image configuration corresponding to the light image projected from the copy. As the drum surface continues its movement, the electrostatic latent image passes through a developing station **26** at which a two-component developing material **27**, which may be of the type disclosed in U.S. Patents 2,618,552 and 2,638,416, is cascaded over the drum surface by means of developing apparatus **28** which may be of the type disclosed in copending application, Ser. No. 393,058, filed Nov. 19, 1953, in the names of C. R. Mayo et al.

In the developing apparatus, developing material is carried by conveyor **29** driven by suitable drive means from motor **30** and is released onto chute **31** and cascades down over the drum surface. The toner component of the developer is partially consumed in developing. Additional toner **32** is stored in dispenser **33** and is released in amounts controlled by gate **34** to the developer to replenish and assure uniform development.

After developing, the xerographic powder image passes a discharge station **41** at which the drum surface is illuminated by a lamp LMP–2, whereby residual charges on the non-image areas of the drum surface are discharged. Thereafter, the powder image passes through an image transfer station **42** at which the powder image is electrostatically transferred to a support surface web **43** by means of a second corona generating device **44**.

The support surface to which the powder image is transferred may be paper, vellum, card stock, etc., that is, continuous and as stated above, may optionally comprise an expendable continuous type xerographic plate on which the powder image is directly formed. The support surface is obtained from a supply roll **45** and is fed over suitably grounded guide rolls **46** and **47**, and over suitable tensioning rolls being directed into surface contact with the drum in the immediate vicinity of transfer corona generating device **44**. After transfer, the support surface is separated from the drum surface and guided into the fusing apparatus of the invention **50**, to be described, whereby the powder image is permanently affixed to the support surface. In most known commercial machines of the type being described, the fusing apparatus has been of the heat fusing type as, for example, disclosed in Crumrine patent U.S. 2,852,651.

After separation of the support surface from the drum, a corona generating device **54** may direct negative electrostatic charge to the residual powder image on the drum surface. Thereafter, the xerographic drum surface passes through a cleaning station **55** at which its surface is brushed by a cleaning brush assembly **56**, rotated by a motor **57**, whereby residual developing material remaining on the drum is removed. The drum surface then passes through a second discharge station **58** at which it is illuminated by a fluorescent lamp LMP–3, whereby the drum surface in this region is completely flooded with light to remove any electrostatic charge that may remain thereon. Suitable light traps are provided in the system to prevent any light rays from reaching the drum surface, other than the projected image, during the period of drum travel immediately prior to sensitization by corona generating device **25** until after the drum surface is completely passed through the developing station **26**.

Referring now to the fuser apparatus **50**, there is illustrated the method and apparatus of the invention in which a vapor of a solvent for the solvent soluble component of the powder image is effective to affix the powder image to the support web. The solvent employed must of necessity be an easily volatilized solvent for the material constituting the powder image and for obvious reasons should be non-explosive. The particular solvent employed depends on the properties of the particular image material and/or base on which the image is to be supported. Trichloroethylene is one solvent particularly suited for image material of the type referred to above. Other suitable solvents include chloroform, carbon tetrachloride, and other chlorinated solvents; the various Freons (believed to be fluorinated lower alkalines); aromatic and aliphatic hydrocarbons such as benzene, toluene, gasoline and gasoline fractions; oxygenated solvents such as ethanol, acetone, ethyl acetate and other alcohols, ketones, esters and the like. In all cases, the particular solvent is appropriately selected for the particular combination of material compositions employed.

The various solvents are characterized by various degrees of toxicity and the problems of minimizing dilution in the ambient atmosphere should be appreciated. The following list taken from various handbooks such as the Handbook of Organic Industrial Solvents, published by the National Association of Mutual Casualty Companies, indicates a summary of allowable maximum concentrations in the atmosphere of sample solvents to maintain the atmosphere below unsafe levels of toxicity. The concentrations are expressed in parts per million (p.p.m.) and as listed include trichloroethylene at 200 p.p.m; chlorethene at 500 p.p.m.; Freon 112 at 1000 p.p.m.; Freon 11 at 1000 p.p.m.; and Inhibisol at 500 p.p.m. These solvents have each been found to accord various degrees of fusing when used in conjunction with developer of a type described, for example, in Patents 2,618,552; 2,638,416; 2,659,670; 2,753,308; 2,788,288; 2,892,794 and Reissue 25,136 as well as commercially marketed products such as 914 Copier Toner which is a trademark of Xerox Corporation of Rochester, New York. It is not intended, however, that the named solvents should in any way constitute a limitation relevant to the instant invention.

The fuser apparatus, as illustrated in FIGURE 1, is comprised of a box-like structure forming a vapor chamber **70** into which the web **43** is continuously passed for windup onto take-up roll **52** shown completely enclosed in the chamber. The chamber is constructed substantially vapor-tight, and is formed of a front wall **71**, side walls **72** and **77** and bottom, top, and rear walls **73**, **74** and **75**, respectively. Defined in front wall **71** is a narrow opening **76** through which the web enters the chamber.

The take-up roll is mounted on an axle **60** journaled for rotation between a pair of parallel extending arm supports **62** secured at their opposite end to a shaft **67** journaled in the side walls. The shaft **67** is under control of a rotary solenoid **68** which when energized causes the take-up roll to be supported within the chamber. When de-energized, as for machine shutdown, the solenoid causes the arms to rock to the position shown dotted against a bumper **69** passing the take-up roll through a two-way swinging split door **64**.

The door is made up of two separate sections each secured via a spring hinge **65** to front wall **71** and which contain overlapping flexible seal members **123** and **124** of silicone impregnated fiber glass strips to provide a substantially vapor tight joint along the line of contact. Each door section is separately comprised of two individual sections hinged together via a spring hinge **122** to permit the roll to pass through the door free and clear after which the door snaps back to close off the chamber. Additional seals **125** secured to the front wall along the side edges of the door sections further prevent the escape of vapor during operational periods. Openings **126** and **127** in the top section each covered by a split seal **127** permit arms **69** to protrude through the door. On startup, as the take-up roll is positioned for operation, the doors are caused to swing inwardly before snapping into their closing position. By this means, excessive solvent absorption in the web as well as vapor escape to the ambient atmosphere is prevented in the event of a power failure or other machine shutdown.

Rotation of the take-up roll is effected via a motor **53** through a slip-clutch **63** adapted to maintain windup at a uniform linear speed. Actual connection is via a belt, not shown, that becomes slack when the take-up roll is advanced out of the chamber by the arm supports **62**.

Supported on a shelf on the bottom wall is a reservoir **80** for containing liquid solvent **81** for the solvent soluble component of the powder image to be fused. Since a certain quantity of solvent is consumed in the process of fusing, the level of liquid solvent is maintained substantially level and constant by means of makeup solvent contained in a dispenser bottle **82** which flows solvent to the reservoir **80** via conduit **83** connected to the reservoir **80** below the liquid level.



The generation of vapor within the chamber is effected by means of a solvent wick **90** formed of felt, cloth, blotting paper or the like. The lower end of the wick is rolled into a wad at the bottom of the reservoir to draw up solvent in the wick and generate a vapor atmosphere along the path of movement of web **43** moving therepast. Preferably, although not necessarily, the wick is arranged and supported to be substantially parallel or otherwise contoured to the path of web movement from the vicinity of opening **76** to the vicinity of its windup onto the take-up roll.

Therefore as the web continues to advance from transfer station **42** on approaching the fuser apparatus **50**, it passes first through opening **76**, then over guide roll **92** and then up onto the take-up roll **52**. From the time of entering the chamber and while still being wound onto the take-up roll, the web is caused to be exposed to a saturated atmosphere of the vapor of the solvent **82**. As can be seen, the web passes with the image bearing surface facing toward the wick member to effect maximum exposure to the vaporized solvent.

As the web winds onto the take-up roll, it does so in spiral-like fashion with each added layer of periphery overlapping against the previously added layer. After a predetermined length of web has been wound, the unit can be stopped as by interrupting the operation and the roll is automatically removed out from the chamber by the action of solenoid **68** through the door **64** outwardly against the tension of pivot **65**. Alternatively, an opening can be provided in the front wall through which the wound roll can be unwound directly in place and severed into desired lengths usually corresponding to dimensions of the reproductions contained thereon.

Whereas it would be expected that the powder image, softened by exposure to the vapor atmosphere of the solvent from the solvent soluble component of the powder image, would continue on windup to absorb solvent to become increasingly soft as to offset onto a surface against which it came into contact, it has been found in accordance with the invention that surprisingly little and only a negligible amount of the softened powder does, in fact, offset. This has been found to be true for either line copy or continuous tone subjects throughout a wide range of operating speeds up to about twelve inches per second. Some variation was found to exist dependent on the texture of surface with the rougher texture papers according lower offset. In any case, the amount of offsetting was found not to smear the image or damage the paper in any way. At the same time, a strong fused bond resulted between the powder image and the web. By this means, therefore, it was found possible to operate the web at speeds in the range of from virtually zero up to on the order of twelve inches per second and above without significant offsetting between adjacent overlapping layers of a wound web, and in all cases, without any smudging of the image previously formed.

On unwinding the web in order to effect severing for its ultimate disposition, it was found that relatively little ventilation was required as compared to such prior art devices, since only vapor absorbed by the web and the powder released into the atmosphere as compared to the larger amounts of vapor of the prior art devices that included both dragout and the absorbent release. Thus, by the instant invention, the solvent consumption per unit of copy has been found to be substantially reduced having completely eliminated the effects of vapor dragout. This has resulted in a more efficient, more economical and yet higher speed vapor fusing method and apparatus as compared to any known devices of the prior art.

Referring now to FIGS. 2 and 3, there is illustrated a variation of the apparatus as described above in connection with FIG. 1. In this embodiment, take-up roll **52** supported on axle **60** is driven via a motor **85** which through gears **86** and **87** drives a timing belt **88** engaging pulley **89**. The pulley is secured to a shaft end of a slip

clutch **99**. A shaft **91**, extending from the clutch, is journaled for rotation in support **93** and has a splined end to receive the axle **60**. The take-up roll in this embodiment is adapted to be exposed at least partially exterior of the chamber at a relatively large opening **94** in the front wall. The web enters near the top of the opening adjacent a lip **95** and then is directed past a wick **90** similarly as above being stretched across the opening onto the take-up roll. In order further to maintain the chamber substantially sealed against leakage of vapor to the surrounding atmosphere, one end of the roll abuts the side wall **77** while a guide plate **101** having a turned end flange **109** supports the axle and abuts the other end of the roll. The guide plate is positioned by means of a crank handle **113**. Since the vapor generated in the chamber is substantially heavier than air, it tends to settle towards the bottom of the chamber.

In order to provide a vapor seal along the bottom of the take-up roll, there is provided a roller **96** adapted to contact lightly against the image-bearing surface of web **43** being wound on take-up roll **52**. The roller is mounted for rotation in a bracket **97** in turn mounted on a pair of pistons **98** each adapted for vertical movement in guideways **102** flange mounted on a shelf plate **112**. The pistons are urged upward to urge the roller against the web being wound by means of resilient, compressed, light tension springs **103**. By this means, the roller **96** is always in contact against the drum surface but as the roll diameter increases, by virtue of the winding of the web, roller **96** is caused to move downward against the urgence of the springs.

To prevent offsetting of the image material to the roller **96**, its periphery contains or is formed of an adhesive material such as Teflon to which a thin coating of silicone oil may be dispensed from a dispensing roll **110** also supported in bracket **97**. A manifold or reservoir **104** having a plurality of uniformly spaced separate dispensing nozzles **107** dispenses oil **111** through tubing **105** and a control valve **106** to the drip nozzle **107**. The oil drips onto roll **110** and uniformly distributes itself over the periphery during rotation thereof and is then presented into contact against the peripheral surface of roll **96**. A drip pan **108** collects excess oil off roll **110**. By this means, a substantial vapor seal is effected along the underside of the take-up roll without smudging the image being contained thereon.

When using the fuser for excessively high speeds of operation, an auxillary heater **116** may be provided. The heater is supported on a bracket **120** pivotally mounted on a rod **121** so that the heater can be placed into operative or inoperative relation relative to the web surface on the roll. The heater is comprised of radiant coils **117** energized from a potential source **118** and is adapted to heat the web and evaporate absorbed solvent contained on the web and its image prior to its being overlapped upon during its windup onto the take-up roll. A suitable blower may be provided to carry off vaporized solvent, vaporized by the effect of heater **116**.

For removal of the take-up roll **52** from the chamber, axle **60** is withdrawn to disconnect from shaft **91** after which take-up roll **52** may be raised from its mounting. Optionally, web **43** wound on roll **52** may be unwound from the chamber directly in place and severed into prescribed lengths as required.

It should be apparent that the size of elements may be controlled by various factors including web dimensions, solvent employed, rate of web movement, developer composition, etc., in order to achieve a required vapor exposure prior to overlapping the web. Minimum width of the chamber may be a function of web width although wider fusers may be employed with narrow webs while height and path length within the chamber may be controlled by solvent, speed of transport, developer material or the like. Typically, it has been found that for an eleven inch web at speeds of 20 feet per minute, employing developer as described in Carlson's Reissue 24,135 and with trichloroethylene as the solvent, images fuse in in about 1½ seconds of exposure before being overlapped onto the take-up roll. The materials of construction for the various elements should preferably not be subjected to chemical attack for the solvent employed. For trichloroethylene, various materials such as stainless steel or nylon have been found suitable.

By means of the invention, therefore, there is provided high speed method and apparatus for vapor fusing xerographic powder images onto a continuous support web on which substantially only that solvent absorbed in the image material and to a minor degree, the web, if of an absorbent material, ever leaves from the chamber. It is to be noted that heat, as here employed, is not essential to the invention and further that the temperature and thermoenergy consumption is far less than required for heat fusing in the absence of vapor. For example, though not in any way to be regarded as an imitation, a temperature of about 70 degrees Fahrenheit is adequate to drive off condensed vapor of the trichloroethylene whereas for heat fusing, the web ordinarily attains a temperature on the order of approximately 240 degrees F.

Therefore, the elimination of vapor dragout, in accordance with the invention, has resulted not only in a much lower dilution to the atmosphere, reducing ventilation requirements, annoying odors, etc., but also the consumption of solvent attributable per unit of surface being fused has been found to be substantially reduced. Thus, by means of the instant invention ambient toxicity is so substantially reduced below safe levels that vapor fusing may now be used on commercial equipment more readily and more safely and in a more economical manner, while at the same time, speeds previously unattainable and impractical for heat fusing or vapor fusing may now be effected by using a vapor fixing technique. This increased efficiency, therefore, produces both economic, comfort and speed advantages not enjoyed by the prior art devices such as to provide a vapor fuser adapted for continuous operation with a moving web.

Since many changes can be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended all matter contained in the drawings and specification shall be interpreted illustrative and not in a limiting sense.

What is claimed is:

**1.** In the method of xerography that includes the steps of forming a loosely supported powder image reproduction with powder material having a solvent soluble component onto a continuous web support surface, and fusing the loosely supported powder substantially permanently onto said support surface, the improvement in the fusing step comprising the steps of:

(a) forming a solvent vapor atmosphere for the solvent soluble component of the powder image and in which the web support is insoluble;

(b) exposing the powder images on said web to said vapor atmosphere for a sufficient time period to enable fusing of the solvent soluble component thereof and winding the web while in said vapor atmosphere into overlapping relation onto a take-up roll adapted to support the web being received thereon at least partially within said vapor solvent atmosphere; and,

(c) removing the wound web having fused powder images thereon from the vapor atmosphere after a predetermined length of web has been wound on said roll.

**2.** The method according to claim **1** in which said take-up roll supports the wound web totally within said vapor atmosphere.

**3.** The method according to claim **1** including the step of applying heat to the web prior to its being overlapped upon.

**4.** The method according to claim **1** in which removal

of the web from said vapor atmosphere is effected by relocating the takeup roll supporting the wound web to a location removed from said vapor atmosphere.

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