May 3, 1966 R. G. OSTENSEN 3,249,088

DEVELOPING TANK UNIT FOR ELECTROSTATIC PRINTING

Filed April 3, 1963 3 Sheets-Sheet 1

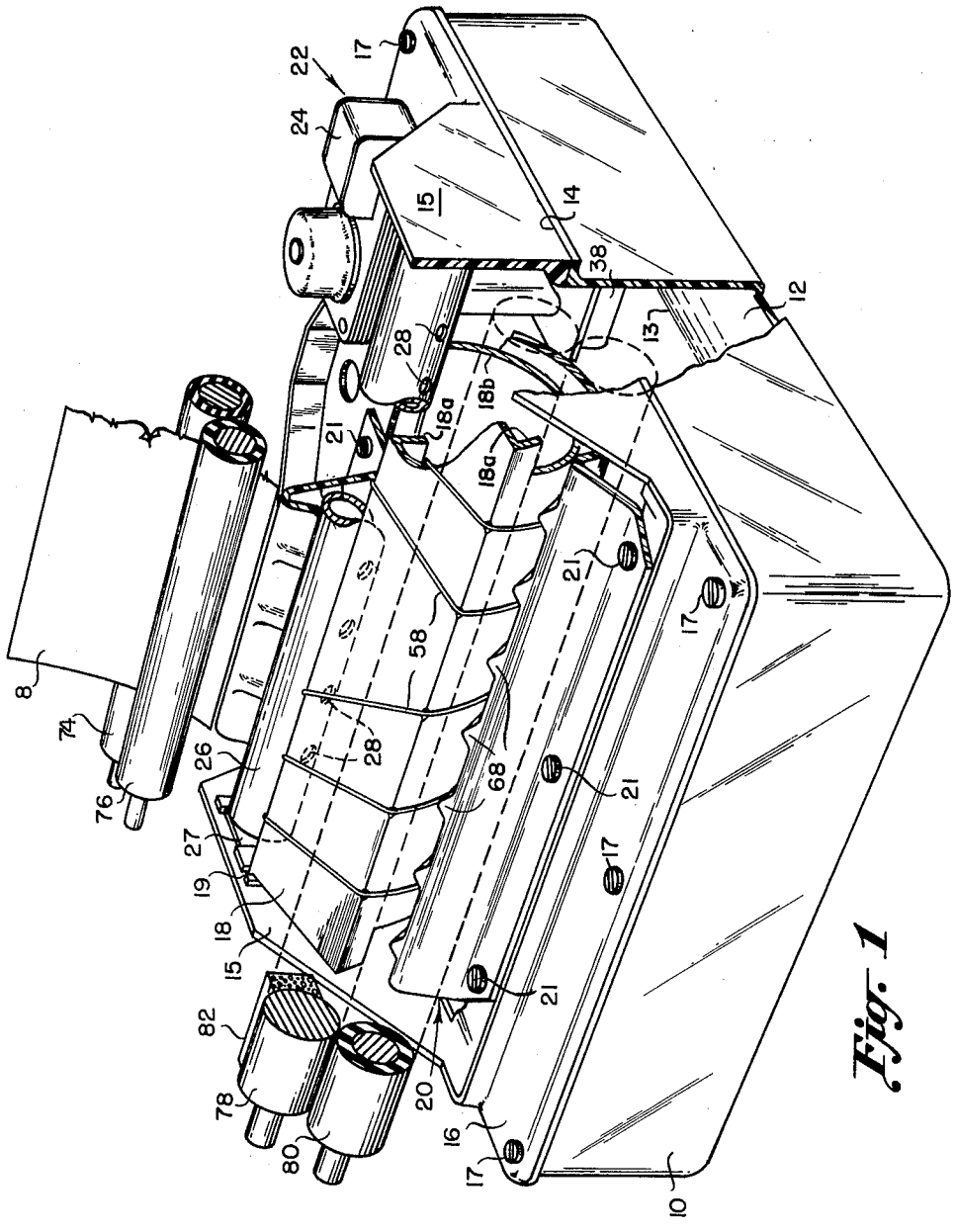


Fig. 1

INVENTOR.
RALPH G. OSTENSEN

BY

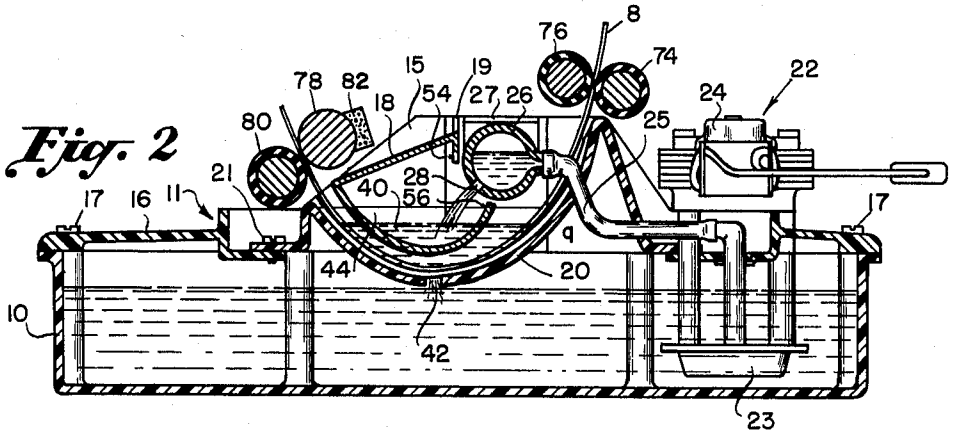
Strauch, Nolan & Neale
ATTORNEYS

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DEVELOPING TANK UNIT FOR ELECTROSTATIC PRINTING

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Fig. 2



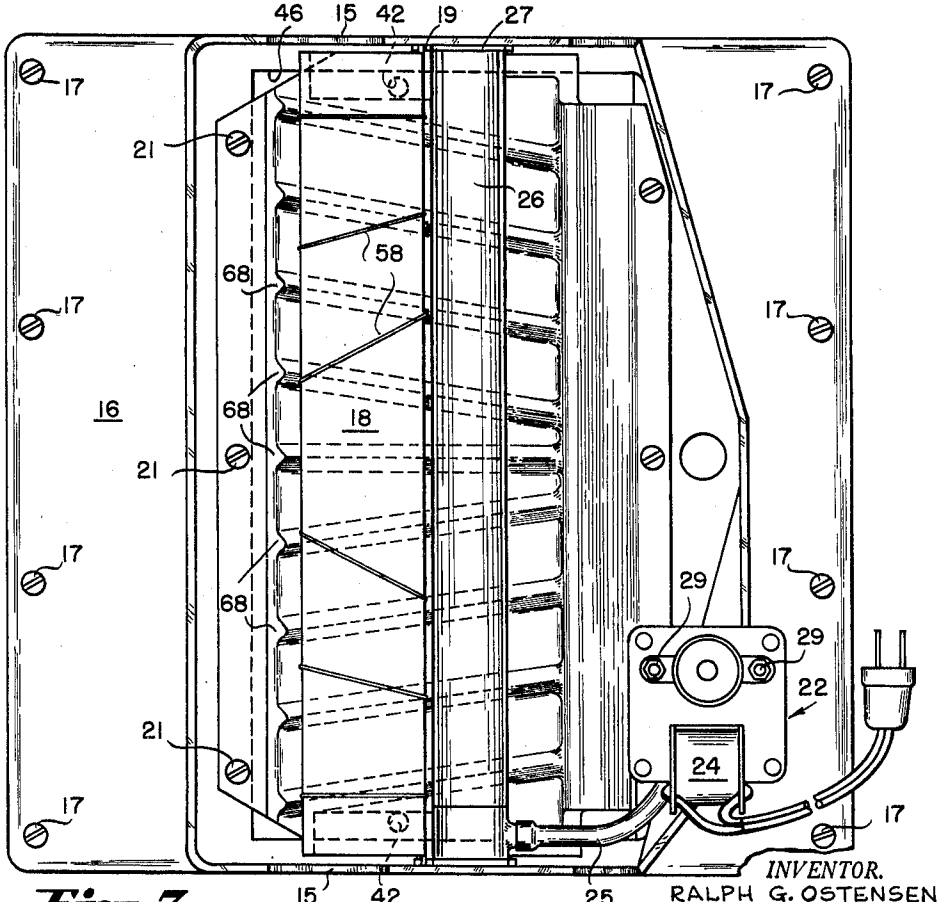


Fig. 3

INVENTOR.
RALPH G. OSTENSEN

BY

Strauch, Nolan & Neale

ATTORNEYS

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DEVELOPING TANK UNIT FOR ELECTROSTATIC PRINTING

Filed April 3, 1963 3 Sheets-Sheet 3

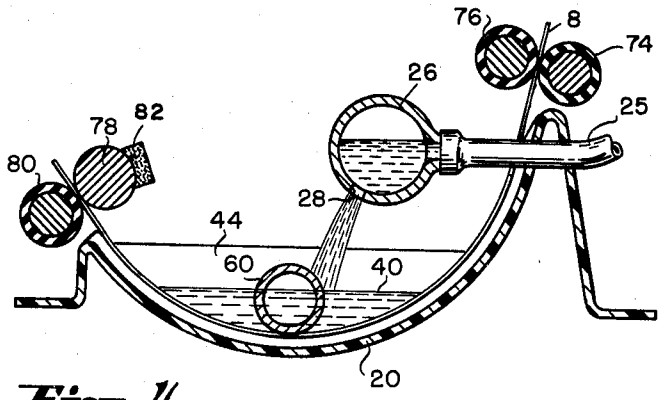


Fig. 4

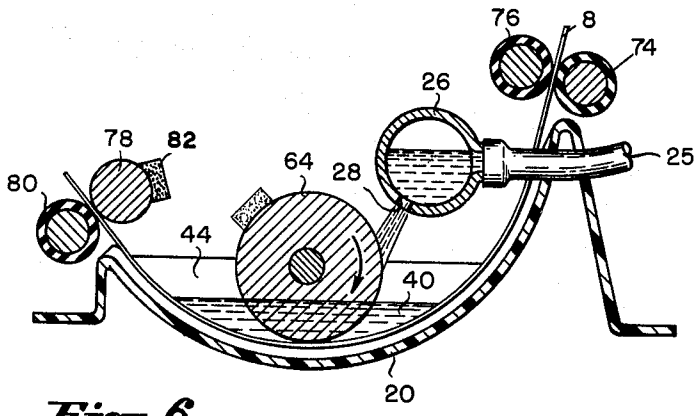


Fig. 6

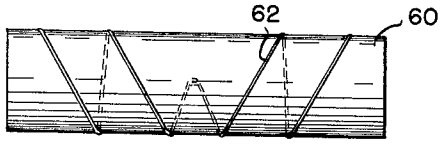


Fig 5

INVENTOR.
RALPH G. OSTENSEN

BY

Strauch, Hofman & Neale

ATTORNEYS

United States Patent Office 3,249,088 Patented May 3, 1966

3,249,088

DEVELOPING TANK UNIT FOR ELECTROSTATIC PRINTING

Ralph G. Ostensen, Morton Grove, Ill., assignor to SCM Corporation, New York, N.Y., a corporation of New York

Filed Apr. 3, 1963, Ser. No. 270,289
17 Claims. (Cl. 118—637)

This application is a continuation-in-part of my patent No. 3,202,526 for "Method and Apparatus for Liquid Development of Latent Images," filed October 5, 1961 and assigned to a common assignee.

This invention relates to the field of photographic developing and more specifically to a tank device for liquid developing of latent electrostatic images which have been placed on photographically coated carriers and particularly carriers of the direct positive paper type.

While the present invention is of general applicability to photographic printing, it will be described in connection with the development on a carrier or sheet of a latent electrostatic image which may be formed in accordance with well-known electrophotography techniques. A carrier, which may be a sheet of paper coated with a photoconductive insulating material such as zinc oxide, may be uniformly charged to have a homogeneous electric field. The electric field is subsequently selectively discharged or released by radiation from an image to be recorded. At locations on the carrier where little or no radiation impinges, the electric field remains sufficiently strong to attract electrostatically charged pigment or color particles and thus produce a graphic copy.

In the prior art, it has been common to use dry electroscopic powder for development of a latent electrostatic image into a visible image. Liquid developers have also been used successfully. The liquid developer offers the advantage that smaller sized pigment particles can be used to provide a higher degree of resolution of the image on the copy carrier than can conveniently be attained with powder development techniques. Although some saturation of the carrier results from the use of a liquid developer, no appreciable time loss or inconvenience is experienced due to the very short drying period required after the carrier is squeezed between squeezing rollers as it emerges from the developing tank.

British Patent 755,486, August 27, 1956 and Australian Patent 227,951, October 2, 1958 are illustrative of prior art attempts to use liquid developer systems. Primary difficulties of prior art systems are that, to produce a visible image of sufficient intensity, undesirable light and dark areas are sometimes present which are referred to as a "halo effect," namely, a dark ring around a light area or a light ring around a dark area. The chief reason for these phenomena is believed to result from distortion of the electric lines of force at the charged surface of the carrier. Prior efforts to reduce the "halo effect" have embodied the use of an electrode means spaced from the surface of the carrier being developed and connected to a source of electrical potential to provide a bias that affects the charged pigments particles. However, the bias voltage in the liquid has the highly undesirable effect of destroying the electrical balance in the liquid developer, resulting in the settling out of the charged pigment particles and hence shortening the useful life of the liquid developer.

Accordingly, a primary object of the present invention is to provide a novel means for producing improved images on a copy sheet. The particular apparatus is adapted to be used in the desk top electrostatic printer disclosed in my copending application Serial No. 249,248, filed January 3, 1963 and now abandoned.

Another object is to provide a novel means for reducing the so-called "halo effect" without decreasing the useful life of the liquid developer. To this end, an intensifier member, in the form of a plate or roller of conductive material may be used which is electrically floating or unconnected to any voltage source. The surface of the intensifier member is preferably located as close to the charged surface of the carrier as possible without causing smearing of the pigment. Where the intensifier member is a roller adapted to contact the charged surface of the carrier, steps must be taken to prevent pigment particles adhering to the intensifier member from overprinting.

A further object therefore is to provide wiper means for removing toner particles from rotary members, such as squeeze rollers, which engage the surface of the carrier on which the pigment particles are doposited during development, thereby preventing streaks and overprinting on the carrier.

Another important object of this invention is to provide an improved liquid distribution system which may include a pump and an apertured header whereby the ratio between the pump's fluid displacement capacity and the header's outflow capacity are so precisely matched that a constant, slightly positive header pressure is maintained at all times regardless of the liquid level in the tank reservoir, whereby gentle header outflow is provided to delay flocculation or settlement of the pigment particles in a liquid developer.

Another object of this invention is to provide a novel circulation system for providing a liquid developer reservoir of substantially uniform size, but constantly changing liquid from a much larger supply reservoir so as to provide improved developing uniformity over increased periods of time without adjustment of the carrier speed during development.

A further object of the present invention is to provide novel lower tank-type carrier sheet guide means at the development locale, to facilitate travel of the carrier through a reservoir of developer, which has in the bottom thereof a drain aperture of lower capacity than the volume of inflow of the developer.

Still another object of this invention is the provision of a novel developing unit sufficiently compact to be installed inside an office type photographic printer as an integral part thereof whereby a latent image on a continuous carrier web or separate sheet may be developed immediately after the image is produced in the carrier before the carrier emerges from the machine.

The present invention comprises a novel pump and tank combination whereby the ratio between the output of the pump and the capacity of the header are so well balanced that the header pressure remains constant at all times regardless of the developer level in the tank reservoir. The header pipe is provided with numerous apertures of a predetermined diameter along its length and has a volumetric capacity precisely balanced with the volumetric output of the pump. Excessive pressure build-up in the header is thus prevented and a controlled flow through the apertures is provided.

The method of operating the apparatus basically involves guiding an exposed photographic carrier in a continuous movement between an upper and lower guiding means through a relatively small pool of liquid developer formed therebetween, the liquid cascading down from the header pipe onto a curved surface of the upper guide means and overflowing onto the lower guide means to form a pool therein. There are two small drain holes in the lower guide means that drain the liquid developer back into the main tank reservoir and their size is calculated to allow less volume of liquid to drain off than is supplied by the header pipe. During continuous operation the build-up of the pool will exceed the capacity of the

lower guide means and the over-flow will return to the main tank reservoir through openings provided in excess of the two drain holes.

These and other objects will become more fully apparent from the claims and from the following detailed description taken in conjunction with the accompanying drawings showing preferred embodiments in which:

FIGURE 1 is a partially cut-away perspective view of the tank showing the relative positions of the ingress feeding means, upper and lower guide means, header piper, pump, and squeezing rollers with a wiper for removing toner particles therefrom;

FIGURE 2 is a schematic sectional view in elevation of the developing unit showing the carrier being moved between the upper and lower guides, through the liquid developer pool and upward toward the squeezing rollers;

FIGURE 3 is a plan view of the developer tank of FIGURE 2 again showing relative locations of associated parts;

FIGURE 4 is a sectional view of an alternate embodiment using a metallic tubing as the intensifier in place of the upper guide of FIGURE 1;

FIGURE 5 is a partial view of the metal tube of FIGURE 4 having a cord of insulating material to prevent overprinting; and

FIGURE 6 is a sectional view of still another alternate embodiment using a driven metallic roller in place of the upper guide of FIGURE 1.

Referring now to FIGURE 1 of the drawings, the developing apparatus of the present invention consists of a tank or container **10** having integrally formed side walls and a bottom wall and being of a size capable of holding a substantial quantity of liquid developer **12**. The upper surface **13** of liquid developer **12** is below top edge **14** of tank **10**. Tank **10** may be of a one-piece molded plastic such as polyethlene which is somewhat transparent, making it easy to observe the level and degree of opaqueness of liquid **12**. Liquid **12** basically consists of a bulk solvent having a high electrical resistivity, such as 10^{10} ohm-cm., and pigment or coloring forming particles that are capable of being maintained as a dispersion in the carrier. While the pigment particles remain effectively dispersed, the liquid developer is opaque and satisfactory for use. When the pigment particles settle, which results from a loss of electrical charge, the liquid becomes clear and, in general, is no longer useful.

The cover **11** for tank **10** comprises an upper section **16** on tank **10** (see FIGURES 1–3) which may be formed of similar plastic and fastened, as by screws **17** to bosses in tank **10** around its top edge **14**, and a lower guide member **20**. Upper section **16** is formed to have a central opening **9** and a pair of side walls **15** having guideways to provide for easy assembly of the main liquid pumping component parts and paper guide member at the development station. An upper carrier guide member which also serves as an image intensifier member **18** having depending side walls **18***a* and a curved lower wall **18***b* (see FIGURES 1 and 2) is secured at opposite ends to upper section side walls **15** at guideways **19**. The lower carrier guide member **20** is attached to upper section **16** as by screws **21** to cover the central opening **9**. Pump-motor unit **24** is secured to upper section **16** by bolts **29** (FIGURE 3) through a further opening. Header pipe **26** is secured to side walls **15** at guideway **27**.

Referring to FIGURE 2, the developer circulation system **22** comprises pump **24** having intake **23** which is immersed in tank **10** and an output tube **25** which discharges into header pipe **26**. A series of small, spaced apertures **28** extend along the full length of header pipe **26** which is disposed laterally across the width of the carrier sheet to be developed. Liquid output from apertures **28** of header **26** falls on the upper surface of guide member **18**, and runs off the lateral edges down onto lower carrier guide member **20**.

Lower carrier guide member **20**, the shape of which

is best illustrated in FIGURE 2, extends upwardly to a position near ingress roller members **74** and **76** which may be mounted as part of the copying machine, and curves downwardly and then upwardly to the egress squeezing roller members **78** and **80**. The general arcuate shape of lower guide member **20** provides a central depressed region in the top wall of the developing tank which serves to provide a small pool **40** of developer. Side edges **44** extend upwardly from the lower arcuate surface to the top of the pool **40** as shown in FIGURE 2. Liquid developer flows over the tops of side edges **44** and falls through openings at **46** back into the large supply of developer in tank **10**.

Pump **24** is so connected as to operate only when the copy machine is in actual use. This is desirable because the life of the liquid developer is somewhat shortened by exposure to air. Thus, it is desirable to provide a pair of small diameter drain holes **42** at the lowermost portion of lower paper guide member **20**. The size of drain holes **42** is so chosen that their combined capacity is somewhat less than the volume of liquid supplied through header **26**. This provides a continuous exchange of liquid developer in pool **40** and a gradual increase in the size of the developer pool as the machine continues to operate. The maximum size of the pool is, of course, determined by the top of side edges **44**.

Because of the somewhat sensitive characteristics of the liquid developer, the ratio between the volumetric capacity of pump **24** and the outflow of developer from apertures **28** are chosen so that the liquid does not spray as though under considerable pressure, but instead flows gently therefrom in relatively low pressure streams. The liquid therefore falls gently on the upper surface of guide member **18** and falls gently off the sides into the central depressed area to form pool **40**.

The carrier sheet **8** as it comes to ingress rollers **74** and **76** has already been charged and selectively discharged to have a latent electrostatic image on the upper surface. Carrier **8** may be of the type disclosed in U.S. Patent No. 3,052,539 to Greig and have a layer of photoconductive material on the upper surface. Those regions which are charged attract the pigment or color particles in the liquid developer while the uncharged regions remain unaffected by the developer.

While lower carrier guide member **20** is made of plastic, upper guide member **18** is desirably made of a conductive material to thereby cause it to produce an added function as an image intensifier. In the prior art, it has been recognized that a light ring appears around a dark area and that a dark ring appears around a light area. This has been referred to as a "halo effect," and stated to result chiefly from the electric field existing between adjacent charged and uncharged areas.

Metal member **18**, in addition to guiding carrier **8** through pool **40**, serves as an image intensifier by reason of providing an electrically conducting surface closely spaced from and facing the surface of carrier **8** carrying the latent electrostatic charge. All lines of force in the electrostatic image are substantially straightened and unified, thereby causing a great improvement in the quality of the developed carrier **8**.

Metal member **18** is not connected to any source of electrical voltage. As best shown in FIGURE 2, member **18** is held in place by pins **54** and **56** which fit into guideway **19** of mounting unit **16**. Since mounting unit **16** is made of plastic, metal member **18** is not even grounded to the copier apparatus and thus may be regarded to be electrically "floating."

It has been found desirable to prevent the surface of carrier **8** from contacting metal member **18** as this tends to streak the electrostatically formed image, which, of course, shows up as streaks of pigment on the carrier. For this reason, a cord **58** of an insulating material, such as ordinary fish line, is wrapped around membed **18**. The adjacent cords (see FIGURE 3) diverge outwardly

on both sides from the center of the carrier when viewed from the direction of carrier movement. This is useful to prevent the leading edges of the carrier sheet from turning under.

It will be noted that lower carrier member **20** is also provided with ridged portions **68** separated by grooves. The ridged portions **68** are similarly oriented to diverge outwardly for the same purpose.

Ridge portions **68** also assist in guiding carrier **8** through developer pool **40** by preventing it from adhering to the inner surface of a lower guide member **20**.

The carrier **8** may be of a continuous web or of separate pieces of paper cut into predetermined lengths at least as great as the distance between the two pairs of rollers **74**, **76** and **78**, **80**. The rollers are part of the machine in which the developer station of this invention works. A latent image on the surface of the carrier **8** may be provided by exposure to a releasing radiation at a position in the machine which lies in the path of carrier **8** and at a location immediately ahead of the developer tank just described. Carrier **8** is moved downwardly into the developing apparatus by two rollers **74** and **76** along a path between the upper guide **18** and the lower guide **20** and into the developer pool **40**. The carrier **8** moves on through the pool **40** and its leading edge is picked up by the pair of squeezing rollers **78** and **80**.

The liquid developer in tank **10** is circulated by the pump **24** up through a tube **25** and into header pipe **26** where it flows out gently (not sprayed) through the apertures **28** by the slight pressure built up within header pipe **26**. The liquid is pumped out at an even rate regardless of the liquid level in the tank **10** as long as the pump inlet is covered, and the relative capacities of the pump **24** and the header pipe **26** are such that pressure never builds up to the point where liquid is ever sprayed from the apertures **28** in the header pipe **22**.

As carrier **8** continues on through the developer pool **40**, it is, as previously mentioned, picked up by the two squeezing rollers **78** and **80** which move the carrier **8** upwardly and out of the developer pool **40** and, at the same time, remove all of the excess moisture from the carrier **8**. Roller **80** is made of a resilient material such as rubber while roller **78** is preferably steel or a similar hard material so that sufficient pressure can be applied to carrier **8** to remove the excess liquid. A wiper **82** is continually pressed against the squeezing roller **78**, wiping it clean of any pigment particles left by the developed carrier **8** as it is squeezed between the two rollers **78** and **80**. This is important to avoid overprinting on the developed carrier **8**.

From the foregoing it is apparent that although the carrier **8** is completely submerged for a short time as it passes through the pool **40**, it emerges from the two squeezing rollers **78** and **80** in a relatively dry condition and is ready for immediate use. It is also apparent that due to the continuous circulation of the developer fluid, the liquid in the pool **40** is continually replenished and is always at maximum developing strength. Thus, no adjustment of the speed of the carrier **8** is ever necessary to provide an effectively constant development time throughout the life of the developer fluid.

Alternate constructions are shown in FIGURES 4 and 6 for the intensifier member **18** of the embodiment shown in FIGURES 1–3. In FIGURE 4 a hollow metal tube **60** serves as the image intensifier. Tube **60** may be placed at the bottom of pool **40** to rest upon lower guide member **20**. As carrier **8** moves through pool **40**, tube **60** rolls across the image carrying surface of carrier **8** and removes any electric field distortion. Tube **60** thus is mounted for free rotation and does not slide or rub along the surface of carrier **8**. The cord **62** of FIGURE 5 may be wrapped about intensifier **60** to prevent any actual contact of the metal roller **60** with carrier **8** to prevent overprinting when pigment particles adhere to the roller.

Referring to FIGURE 6, a further embodiment is shown where the intensifier member is a metal tube or roller **64** that may be mounted for rotation in suitable bearings (not shown), and driven as by a pulley (not shown) at such speed as to have a surface velocity equal to the speed of carrier **8** as it passes through pool **40**. Roller **64** may contact the surface of carrier **8** and be provided with a wiper, such as a sponge, to remove any pigment particles that adhere to its surface to prevent overprinting. Alternatively, a cord of insulating material may be wound around roller **64** as shown in FIGURE 5 to prevent contact of roller **64** and carrier **8**.

All other parts of the embodiments shown in FIGURES 4 and 6 that are not specifically mentioned may be identical to those of the embodiment of FIGURES 1–3.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and non-restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed and desired to be secured by United States Letters Patent is:

1. In a liquid developer station for immersing a photographic carrier having an electrostatic latent image at one surface thereof comprising a tank of non-conducting material serving as a reservoir for a liquid developer having electrostatically attractable pigment particles therein; carrier ingress means adjacent one end of said tank; carrier egress means adjacent another end of said tank; and guide means on said tank to guide said carrier through said liquid developer at a position between said ingress and egress means; the improvement consisting of an intensifier member of conductive material positioned along the path of the carrier at the position where the carrier is immersed in said liquid, and means for spacing said intensifier member out of rubbing contact with, but closely to the surface of the electrostatic image on the carrier, said intensifier member being free of any bias voltage.

2. The developer station as defined in claim **1** wherein said means for spacing comprise non-conductive spacer means juxtaposed on a part of the surface of said intensifier member facing the image bearing carrier surface to prevent rubbing contact between said intensifier member and said carrier.

3. The developer station as defined in claim **1** wherein said intensifier member is stationary and has a wall facing the image bearing surface of said carrier that is at least as wide as the carrier sheet and extends substantially parallel to the direction of movement of the carrier sheet for a distance equal to at least half of the length of the immersed path for the carrier.

4. The developer station as defined in claim **3** wherein said spacer means comprise a cord of insulating material carried on the intensifier member and placed on said facing wall to prevent rubbing contact between said intensifier member and said carrier.

5. The developer station as defined in claim **1** wherein said intensifier member is mounted for rotation and has a wall facing the image bearing surface of said carrier adapted for movement at a speed substantially equal to the speed of said carrier through the reservoir.

6. The developer station as defined in claim **5** wherein said intensifier member is mounted for free rotation and is driven by contact with the carrier surface.

7. The developer station as defined in claim **5** wherein said intensifier member is rotated by a power drive, the speed of which is substantially equal to the speed of said carrier.

8. The developer station as defined in claim **7** wherein the intensifier member is a roller, and further having wiper means fixedly mounted relative to said tank and in rubbing contact with said roller to remove pigment par-

ticles from the roller surface to thereby prevent overprinting.

9. In a developer station for converting a latent electrostatic image on a surface of a carrier member to a visible image by use of a liquid developer containing pigment particles, means for applying the liquid developer to the image containing surface of said carrier; a pair of squeezing rollers mounted out of contact with said liquid developer so that the carrier passes therebetween as it leaves the developer station for removing excess liquid from the carrier; one of said squeezing rollers having a surface of conductive material and the other of said squeezing rollers having a surface of compressible material; said one roller being adapted to contact said image containing surface; means for guiding said wetted carrier to pass between said rollers; and wiper means for contacting said one roller effective to erase substantially all pigmented images from said one roller to prevent overprinting on said carrier.

10. In a photographic developing station, a large volume main tank having bottom and side walls for holding a relatively large supply of liquid developer; a top member having a depressed portion serving as a guide surface for a carrier, pre-cut into individual sheets, to be developed and for forming a relatively small pool of liquid; means for pumping liquid from said main tank to the depressed portion; said depressed portion having a relatively small aperture at the bottom thereof for draining liquid from said small pool back into said tank at a rate slower than the rate of pumping liquid into said pool, and overflow means located at said depressed portion serving to limit the maximum amount of liquid in said small pool.

11. The developing station as defined in claim 10 wherein said top member is releasably attached to said tank side walls, the guide surface for the carrier comprises a plurality of spaced apart ridges and grooves to guide an exposed photographic carrier through said depressed portion, and said top member further comprises transverse end walls and a plurality of low capacity apertures in the grooves at the lowestmost portion of said depressed portion whereby said liquid developer forms a pool which overflows into said tank by cascading over said end walls and drains through said plurality of apertures when the station is not in use.

12. A one-piece plastic over-flow guide means for a photographic carrier adapted for use on a tank containing a liquid developer having pigment particles comprising side walls and a bottom wall, said bottom wall being arcuate in shape, having sequentially alternate ridges and grooves substantially parallel to the direction of movement of said carrier through said liquid developer, and having at least one low capacity orifice in the lowest portion of said bottom wall to facilitate drainage during idleness, the remaining portions of said guide means being substantially imperforate plastic.

13. An electrostatic latent image developer station apparatus for use with a liquid developer to convert a latent electrostatic image on an upper surface of a carrier to a visible image on the carrier surface comprising in combination:

(a) a tank having a bottom wall and side walls, for holding a comparatively large supply of liquid developer composed of charged pigment particles as a dispersion in a high dielectric liquid carrier;

(b) a cover for said tank comprising:

(1) a support portion mounted at its edges on the side walls of the tank and having a central opening;

(2) a lower guide member mounted to said support portion to substantially close said central opening, said lower guide member having a curved surface to serve as means for guiding the carrier through a comparatively small pool of liquid developer;

(3) side edges on said lower guide member which together with said curved surface form a reservoir for establishing said pool of liquid developer above the liquid developer in said tank, there being small drain apertures in the lowermost portion of said lower guide member to continuously drain out liquid developer from said pool, and the top of said side edges serving as overflow means to limit the maximum size of said pool; and

(4) a pair of upstanding walls on said support portions at opposite sides of said central opening and having guideways;

(c) a header extending between said upstanding walls and secured in said guideways, said header having a plurality of apertures extending across the entire width of the carrier;

(d) an upper carrier guide member made of conductive material to straighten and intensify the lines of force of the latent electrostatic image and mounted above said lower guide member and positioned beneath the header so that liquid developer passing through the header apertures falls by gravity flow onto said upper guide member and into said small pool;

(e) a motor mounted on said support portion and connected to drive a pump having an intake member located in said tank;

(f) a fluid conduit connected between said pump and said header, the capacity of said pump and the size and number of said header apertures being matched to provide a uniform liquid flow rate from said header apertures that is under a very slight pressure;

(g) ingress roller means for driving the carrier through said pool of developer and between said upper and lower guide means;

(h) upper and lower egress roller means located at the output side of said lower guide means for removing the carrier from said developer, the lower egress roller having a surface of compressible material, the upper egress roller having a metal surface; and

(i) wiper means on said upper roller for removing pigment particles which adhere to said upper roller surface to prevent overprinting on the carrier.

14. A developing tank for containing liquid developer for developing visible images from latent electrostatic images on a carrier surface comprising: a tank member having a bottom wall and side walls; an upper section detachably mounted on the upper portions of said tank member side walls and extending over said tank member substantially parallel to the bottom wall thereof, said upper section having a central opening therein; a guide member detachably mounted on said upper section and having an arcuate shaped portion which substantially closes said central opening; means for transferring liquid from said tank member to said guide member; and means for enabling liquid transferred to said guide member to return slowly to said tank member.

15. A developing tank for containing a liquid developer for use in converting a latent electrostatic image on an upper surface of a carrier to a visible image on the carrier comprising:

(a) a tank having a bottom wall and side walls for holding a comparatively large supply of liquid developer;

(b) an upper section detachably mounted on the upper portions of said side walls and having a central opening therein;

(c) an overflow guide means detachably mounted on said upper section to substantially close said central opening and having substantially parallel side walls and a bottom wall, said bottom wall being arcuate in shape, having sequentially alternate ridges and grooves substantially parallel to said side walls, and

having at least one low capacity orifice in the lowest portion thereof, the remaining portions being substantially imperforate to prevent liquid from penetrating therethrough; and

(d) means for transferring liquid developer from said tank to said overflow guide means.

16. The developer station defined in claim **1** wherein said intensifier has a substantially planar upper surface with side walls depending therefrom and a curved bottom wall extending from one of said side walls in a direction substantially parallel to said guide means.

17. The developer station defined in claim **1** wherein said intensifier member is partially submersed in said liquid developer.

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CHARLES A. WILLMUTH, *Primary Examiner.*

WILLIAM D. MARTIN, *Examiner.*