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Egnaczak et al.

[15] 3,658,687

[45] Apr. 25, 1972

[54] APPARATUS FOR FORMING IMAGES WITH APPLICATOR, SHEARING, SMOOTHING AND CLEANING MEANS

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[21] Appl. No.: **876,641**

[52] **U.S. Cl.** **204/300**
[51] **Int. Cl.** **B01k 5/02**
[58] **Field of Search** .... 204/299, 300; 355/3, 4, 15, 355/17; 118/637 LX, 261, 203, 223, 224; 117/37 LE, 111; 101/425, 167

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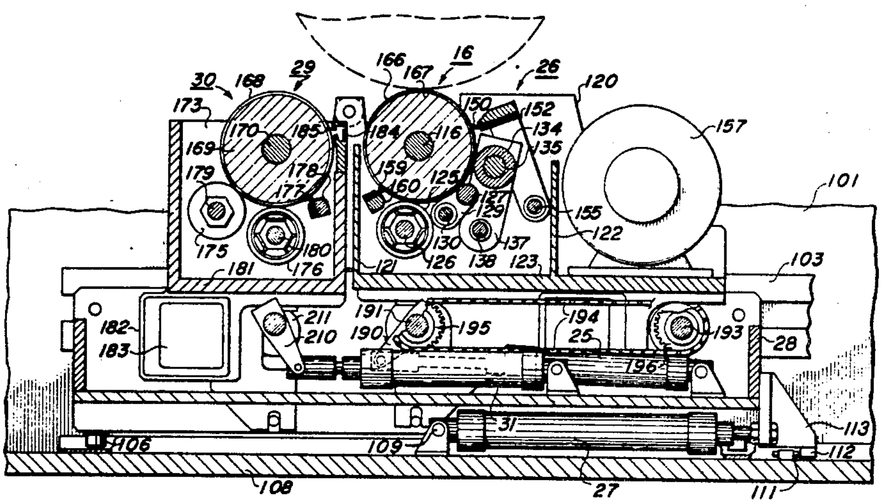
[57] **ABSTRACT**

An imaging electrode assembly for forming photoelectrophoretic images in automated machines. Various components surrounding the electrodes prepare them to aid in image formation. One roller electrode is driven past an imaging suspension applying and leveling apparatus, a suspension shearing apparatus and suitable surface wipers. Another roller electrode passes cleaning brushes and wetting apparatus to remove materials picked up on its surface during its action in the photoelectrophoretic imaging machine cycle.

26 Claims, 6 Drawing Figures



Patented April 25, 1972 3,658,687

5 Sheets-Sheet 1

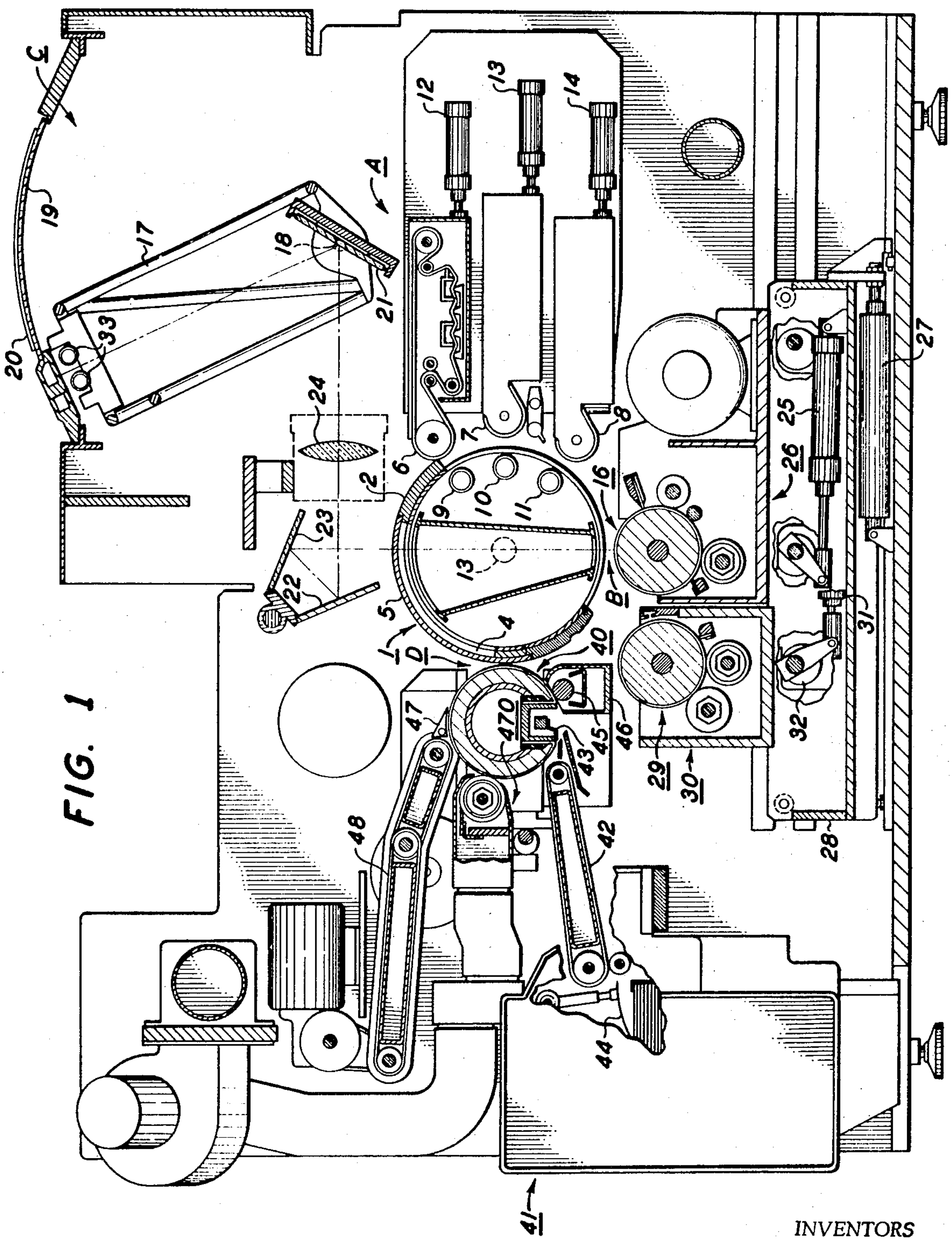


FIG. 1

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ATTORNEY

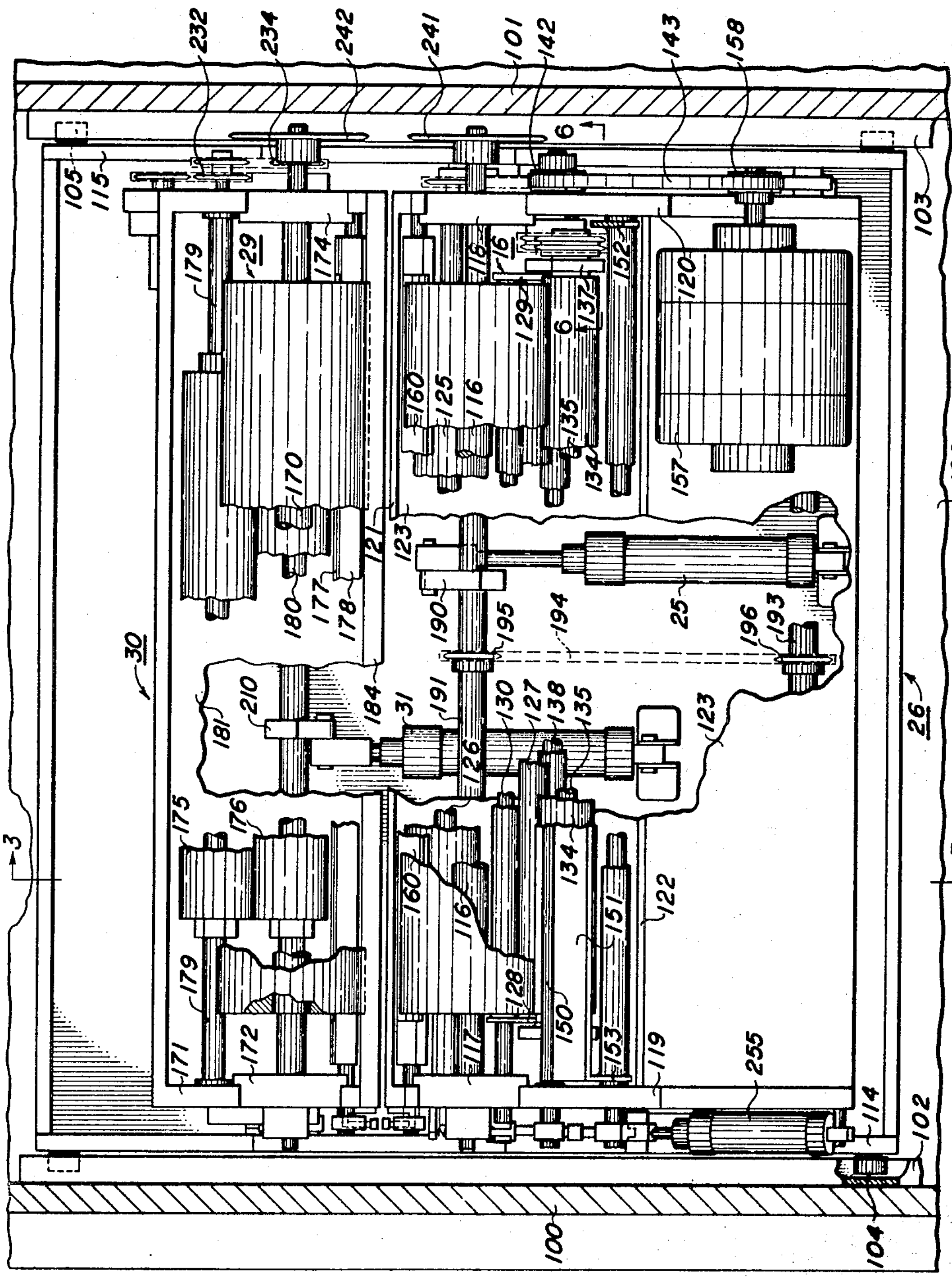

FIG. 2

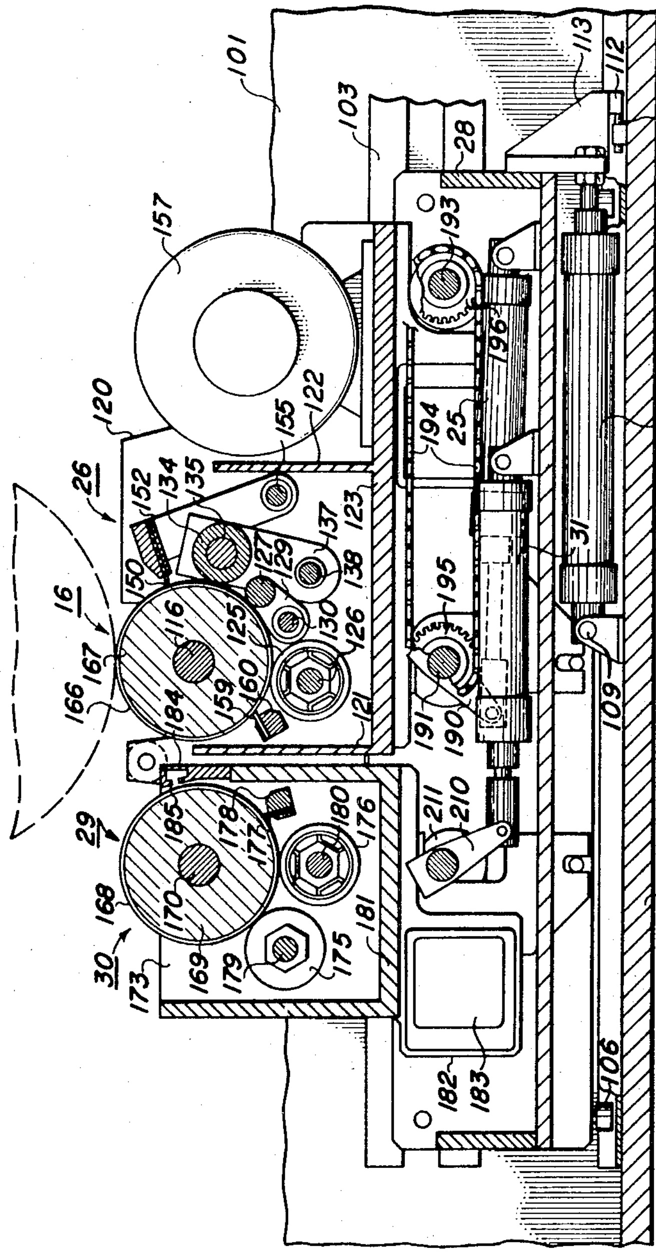
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FIG. 3

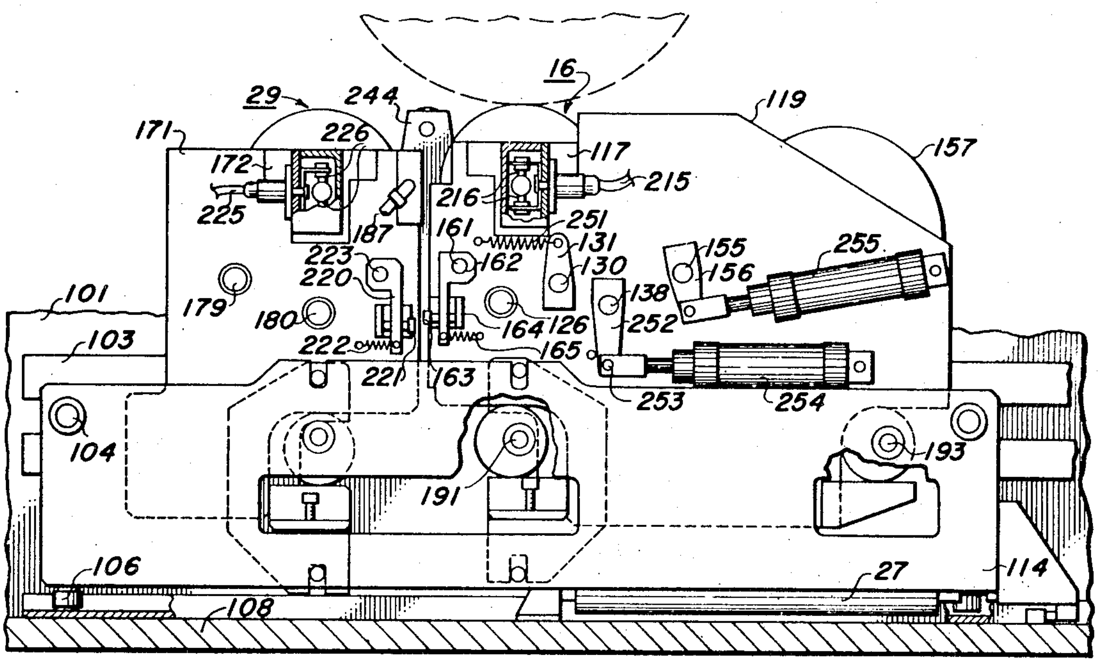
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FIG. 4

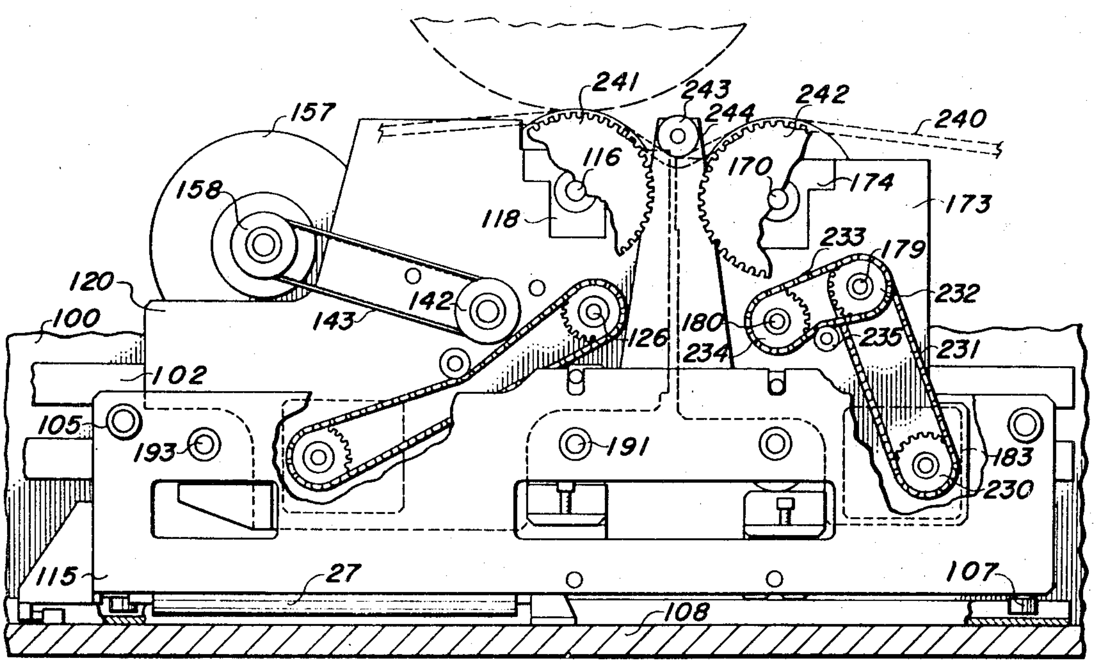
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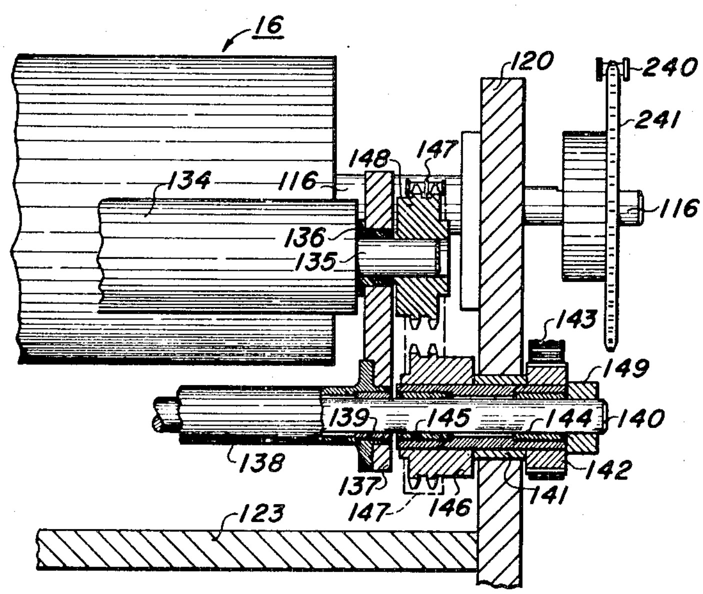
FIG. 5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123

FIG. 6

APPARATUS FOR FORMING IMAGES WITH APPLICATOR, SHEARING, SMOOTHING AND CLEANING MEANS

This invention relates to imaging systems and more specifically to an improved imaging electrode assembly.

Recently, a new invention was disclosed for forming black and white or full color images through the use of photoelectrophoresis. The inventions described in U.S. Pat. Nos. 3,384,488; 3,384,566 and 3,383,993 disclose a system where photoelectrophoretic particles migrate in image configuration providing a visual image at one or both of two electrodes between which the particles are placed in suspension. Thy particles are photosensitive and apparently undergo a net change in charge polarity or a polarity alteration by interaction with one of the electrodes upon exposure to activating electromagnetic radiation. No other photosensitive elements or materials are required; hence, this provides a very simple and inexpensive imaging technique. Mixtures of two or more differently colored particles can secure various colors of images. Particles in these mixes may have overlapping or separate spectral response curves and are usable in subtractive color synthesis. The particles will migrate from one of the electrodes under the influence of an electric field when struck with energy of a wavelength within the spectral response of the colored particles.

Apparatus has been invented to better utilizes the above process. For example, a continuous imaging machine was disclosed in U.S. Pat. No. 3,427,242 depicts apparatus for utilizing the photoelectrophoretic process of the above patents. Copending application Ser. No. 876,976 filed on Nov. 12, 1969 in the names of Raymond K. Egnaczak and Gino F. Squassoni and entitled Automated Imaging Machine is a more sophisticated embodiment of a machine utilizing the new process to produce true color reproductions of original documents or the like. In order to form a particularly good image with the apparatus described therein one or more imaging electrodes must interfere with the injecting electrode or imaging member under the proper conditions for photoelectrophoretic imaging to occur. This must be accomplished automatically and precisely with proper components engaged for processing to be achieved.

Therefore, it is an object of this invention to improve imaging electrode mechanisms.

Another object of this invention is to automatically provide imaging suspension at the imaging member under the proper electrophoretic conditions.

Another object of this invention is to ink and clean electrodes for use in automated photoelectrophoretic imaging systems.

Yet another object of this invention is to supply imaging suspension ready for imaging between electrodes of a photoelectrophoretic imaging system.

These and other objects and advantages will become apparent to those skilled in the art after reading the following description taken in conjunction with the accompanying drawings wherein:

FIG. 1 schematically illustrates a preferred embodiment of a machine for forming photoelectrophoretic images;

FIG. 2 is a plan view partially broken away to show hidden parts of the imaging electrode assembly;

FIG. 3 is a sectional view taken along line 3—3 of FIG. 2;

FIG. 4 is a side view, with hidden parts dotted, of the imaging electrode module;

FIG. 5 is a side view, with hidden parts dotted, of the imaging electrode module as viewed from the side opposite FIG. 4; and

FIG. 6 is a partially sectioned view taken along line 6—6 of FIG. 2.

The invention herein is illustrated and described in a preferred environment embodiment operating in conjunction with other apparatus to automatically and continuously produce images of predetermined optical objects. Nevertheless, the invention need not be confined to such an embodiment and should be construed broadly within the limitations of the claims. It may be that other processes or apparatus will be invented having similar needs to those fulfilled by the apparatus described and claimed herein and it is the intention herein to describe an invention for use in other apparatus than in the embodiment shown. Various specific apparatus is described for accomplishing a particular function but any equivalent structure can be substituted and still be within the scope of the invention.

OPERATION OF THE BASIC PHOTOELECTROPHORETIC SYSTEM

A detailed description of the operation and theories relating to the actual imaging system automated by this invention and discussing the interaction of the photoelectrophoretic particles in the suspension used for image formation is found in the above cited patents. The imaging system therein described and which can be employed in the apparatus described herein operates by producing electromagnetic radiation in image configuration to which the individual photoelectrophoretic particles within the suspension are sensitive. The activating radiation and an electric field across the imaging suspension combine between two electrodes in the imaging area. An electrode referred to as the "transparent injecting electrode" is maintained electrically positive relative to "imaging electrodes" interfacing with it at the imaging area across the photosensitive suspension. Therefore, particles within the suspension that are negatively charged will be attracted to the relatively positive, transparent injecting electrode.

The "injecting electrode" is so named because it is thought to inject electrical charges into activated photosensitive particles during imaging. The term "photosensitive" for the purposes of this invention refers to the property of a particle which, once attracted to the injecting electrode, will alter its polarity and migrate away from the electrode under the influence of an applied electric field when exposed to activating electromagnetic radiation. The term "suspension" may be defined as a system having solid particles dispersed in a solid, liquid or gas. Nevertheless, the suspension used in the embodiment of this invention described herein is of the general type having a solid suspended in a liquid carrier. The term "imaging electrode" is used to describe that electrode which interfaces with the injecting electrode through the suspension and which once contacted by activated photosensitive particles will not inject sufficient charge into them to cause them to migrate from the imaging electrode surface. The "imaging zone" or "imaging area" is that zone between two electrodes where photoelectrophoretic imaging occurs.

The particles within the suspension are generally insulating when not struck by activating radiation within their spectral response curve. The negative particles come into contact with or are closely adjacent to the injecting electrode and remain in that position under the influence of the applied electric field until they are exposed to activating electromagnetic radiation. The particles near the surface of the injecting electrode make up the potential imaging particles for the final image to be reproduced thereon. When activating radiation strikes the particles, it makes them conductive "creating" an electrical junction of charge carriers which may be considered mobile in nature. The negative charge carriers of the electrical junction orient themselves toward the positive injecting electrode while the positive charge carriers move toward the imaging electrode. The negative charge carriers near the particle-electrode interface at the injecting electrode can move across the short distance between the particle and the surface of the electrode leaving the particle with a net positive charge. These polarity altered, net positively charged particles are now repelled away from the positive surface of the injecting electrode and are attracted to the negative surface of the imaging electrode. Accordingly, the particles struck by activating radiation of a wavelength with which they are sensitive, i.e., a wavelength which will cause the formation of an electrical junction within the particles, move away from the injecting electrode to the imaging electrode leaving behind only particles which are not exposed to sufficient electromagnetic radiation in their responsive range to undergo this change.

Consequently, if all the particles in the system are sensitive to one wavelength of light or another and the system is exposed to an image with that wavelength of light, a positive image will be formed on the surface of the injecting electrode by the subtraction of bound particles from its surface leaving behind particles in the unexposed areas only. The polarities on the system can be reversed and imaging will occur. The system may be operated with dispersions of particles which initially take on a net positive charge or a net negative charge.

The imaging suspension may contain one, two, three or more different particles of various colors having various ranges of spectral response. In a monochromatic system the particles included in the suspension may be of any color and produce any color and the particle spectral response is relatively immaterial as long as there is a response in some region of the spectrum which can be matched by a convenient radiation exposure source. In polychromatic systems the particles may be selected so that particles of different colors respond to different wavelengths.

For photoelectrophoretic imaging to occur, these steps (not necessarily listed in the sequence that they occur) take place: (1) migration of the particles toward the injecting electrode due to the influence of the field, (2) the generation of charge carriers within the particles when struck with activating radiation, (3) particle deposition on or near the injecting electrode surface (4) phenomena associated with the forming of an electrical junction between the particles and the injecting electrode, (5) particle charge exchange with the injecting electrode, (6) electrophoretic migration toward the imaging electrode, and (7) particle deposition on the imaging electrode. This leaves a positive image on the injecting electrode.

After the image is formed on the injecting electrode the electrode may be brought into interface with a transfer member which has a charge polarity opposite to that of the imaging electrode. The injecting electrode is now maintained negative relative to the transfer member. The particles having a net negative charge will be attracted to the relatively positive transfer member. If a support material is interposed between the transfer member and the particle image, the particles will be attracted to the support material. Therefore, a photographically positive image can be formed on any support material.

THE MACHINE COMPONENTS

Referring now to FIG. 1, a preferred embodiment for an automated machine to produce images according to the aforementioned process is shown. An injecting electrode **1** forms a portion of a transparent cylinder member held in a housing **2** and is journaled for rotation in the direction indicated by the arrow about a shaft **3**. The injecting electrode **1** is made up of a layer of optically transparent glass **4** overcoated with a thin optically transparent layer **5** of tin oxide or other electrically conducting material. A particular material suitable for this electrode is available under the name of NESA glass manufactured by Pittsburgh Plate Glass Company, Pittsburgh, Pa. The injecting electrode **1** is formed as a portion of a cylinder housed within the metal housing frame **2**.

The machine shown schematically in FIG. 1 is positioned where the injecting electrode cylinder portion is about to be rotated in a predetermined path to a cleaning station labeled A whereat a plurality of cleaning members such as belts **6, 7** and **8** contact the conductive surface **5** of the injecting electrode. On the opposite side of the injecting electrode held stationary within the machine frame are lamps **9, 10** and **11** juxtaposed to the belts **6, 7** and **8** respectively. When activated, the lamps send flood light illumination through the transparent injecting electrode at the contact areas between the electrode and the cleaning belts. Each of the belts are activated by one of the cylinders **12, 13** and **14** to contact the injecting electrode **1**. These cylinders operate to press the belts against the conductive surface of the injecting electrode in order to clean it.

The next station in the path of movement of the injecting electrode is the imaging station B. Here, on the first pass of the injecting electrode **1** through station B the first imaging member, the imaging electrode **16** interfaces with the conductive surface **5** of the injecting electrode **1**.

The optical system at station C projects an image to the imaging zone between the electrodes **1** and **16** at station B. The optical system has a lamp carriage **17** journaled at an axis **18** to oscillate in a path indicated by the arrows. A document **20** is positioned at the platen **19**. The lamps are shown at the start of scan position and as the injecting electrode **1** passes through the imaging area at station B the lamps move across the platen **19** projecting an image at station B through suitable mirrors **21–23**, a lens **24** and the transparent electrode **1**.

The imaging electrode roller **16** moves in rolling interface relation with the conductive surface **5** of the injecting electrode **1** and functions both to supply suspension to the injecting electrode and to image that suspension between the injecting electrode surface **5** and the surface of the electrode **16**.

The injecting electrode continues to rotate at a constant velocity through a complete rotation of the predetermined path. It travels without interacting with any elements located around the periphery of the path until it again reaches station B at the imaging zone. Now, however, the injecting electrode **16** has been moved out of its interfacing position by operation of a cylinder **25** which lowers the electrode **16** and the housing **26** supporting it. Further, a cylinder **27** moves a carriage **28** along a horizontal path carrying with it the housing **26** which supports the imaging electrode **16**. Also moved in the carriage **28** is a second imaging member, the imaging electrode **29** within a housing **30** maintaining it. A cylinder **31** operates through an eccentric **32** to raise the housing **30** and the second imaging electrode **29** at the imaging zone at the imaging station B of the machine. The second imaging electrode **29** moves in rolling interface with the injecting electrode surface **5** as that surface passes through the imaging station B. At this time the original **20** on the platen **19** is again illuminated by the scanning lamps **33** at the optical system station C. The scan is synchronized with the movement of the injecting electrode to project a flowing image in registration with the first projection and moving at the same rate as is the surface **5** at the imaging zone.

The injecting electrode **1** then passes into the transfer station D. At station D is a transfer roller **40**. A sheet of support material held in the supply tray **41** is lifted therefrom and is carried through a vacuum transport **42** to the transfer roller **40**. It is gripped by a gripper mechanism **43** on the transfer roller **40** and rotated to the injecting electrode **1** passing at station D. Before the sheet **44** contacts the surface **5** of the injecting electrode **1** it is moistened with a liquid that will aid in transferring the particles of the suspension on the surface **5**. The wetting is accomplished by a wetting bar **45** rotated in a pool of suitable wetting material held within a tank **46**. The transfer member **40** rotates the support material **44** in rolling contact with the surface **5** of the injecting electrode **1** under the influence of a suitable electric field causing the particles forming the image on the injecting electrode to be transferred to the support material. The support material is removed from the transfer member by picker fingers **47** and a release mechanism on the grippers. Next it is carried on a vacuum transport **48** to a fixing station E where it is heated or otherwise fixed to form a permanently bonded image on the support material which is then deposited in some suitable receptacle.

THE IMAGING ELECTRODE ASSEMBLY

The image forming process occurs in the imaging zone at station B at the interfacing between the injecting electrode **1** and an imaging electrode. It is at this interface that the photoelectrophoretic pigments are brought between the injecting and the imaging electrodes for processing under an applied field and image radiation coming from the optical system at station C.

The imaging electrode module fits between two machine frames **100** and **101**. The unit slides along a set of guide rails **102** and **103** by nylon or other low friction material rollers **104** and **105** mounted on the module carriage **28** to permit easy shuttling of the carriage back and forth along the rails **102** and **103**. Other guide rollers **106** and **107** fit into rails along the bottom machine frame **108** and are fastened along the bottom of the carriage **28** to aid in the movement of the carriage relative to the machine frames and the injecting electrode.

The entire carriage **28** is shuttled back and forth by a cylinder **27** mounted through a clevis mount **109** to the machine bottom frame **108**. The extreme position of the cylinder **27** movement is determined by an adjustable carriage return stop **111** which interacts with a flange **112** on the carriage bracket **113**. The carriage side walls **114** and **115** are the module boundaries of the imaging electrode unit and have the guide rollers **104** and **105** protruding therefrom. Mounted on and actually formed as part of the carriage are the first and second electrode imaging tanks **26** and **30** respectively.

Within the first imaging electrode tank is the imaging electrode **16** mounted on its shaft **116** fastened at each end of the imaging tank through end caps **117** and **118** fitted into the tank side walls **119** and **120** respectively. The first imaging tank **26** itself is broken into two sections. The first is the suspension applicator section which houses the first imaging electrode **16** and mechanisms to apply and treat imaging suspension to it. The tank is composed of an end and middle wall **121** and **122** respectively and a bottom plate **123**. The second section of the first imaging electrode tank is the mount section which is open at its end and adapted for maintaining various connections motors and the like used in the function of the invention.

Located in the applicator section of the first imaging electrode tank are the mechanisms necessary to form a layer of suspension on the first imaging electrode **16** for imaging at the imaging zone. There is a suspension supplying brush **125** which is adapted to supply imaging suspension to the roller **16** from a supply thereof held within the first imaging tank. The imaging suspension supply brush **125** brings the suspension from the bottom of the applicator portion of the tank **26** to the surface of the first imaging electrode **16**. The brush is mounted on a shaft **126** which is supported through bearings in the first imaging tank walls **119** and **120**.

In order to ensure that a smooth layer of suspension reaches the intersection of the first imaging electrode with the injecting electrode, a smoothing rod such as a wound wire rod **127** is made to move into interface with the imaging electrode **16**. The rod can be grooved, smooth, knurled or have any surface for pressing a uniform thin layer of suspension. The smoothing rod is mounted by two support arms **128** and **129** to a pivot shaft **130** which protrudes through the arms **128** and **129** into the side walls **119** and **120** of the first imaging electrode tank. The pivot shaft **130** is preferably a torque tube which aids in applying uniform force across the smoothing rod functioning with the surface of the first imaging electrode **16**. The torque tube passes through suitable bearings extending through the tank wall **119** and joins with a crank arm **131** pressed onto it.

Next in the path of rotation of the first imaging electrode **16** after the contact with the suspension applying brush **125** and the smoothing rod **127** is interaction with the shear roll **134**. The reason for optionally applying a shear roll against the imaging suspension prior to imaging is included because certain imaging suspensions operate to form better color images after a shear stress has been applied thereto. For a detailed explanation of the theories relative to this phenomena and alternative mechanisms usable therewith see copending application Ser. No. 764,721 filed in the name of E. Zucker on Oct. 3, 1968 and entitled Imaging Process. The shear roll **134** is moved into and out of operating relationship with the first imaging electrode **116** as required by the following mechanism. The roller is mounted on a shear roll shaft **135** which in turn is held through a bearing to crank arm **137** and through a similar bearing to a similar crank arm on the opposite end of the shaft. Greater detail for this mechanism is shown in FIG. 6. Also mounted through to the crank arm **137** is the torque tube **138**. The drive shaft **140** of the torque tube **138** slips through the bearing **139** in the crank arm **137**. The torque tube **138**, however, is wedded to the crank arm **137** and that is the driving mechanism to rotate the crank arm and the shear roll into a position of contact with the first imaging electrode. The torque tube shaft passes through the tank wall **120** through an Oilite bearing.

On the outboard side of the tank wall **120** the shaft mounts to a timing belt pulley **142** which is driven by a timing belt **143**. The pulley **142** is separated from the torque tube shaft **138** by a bearing **144**. That bearing functions with bearing **145** to turn the sprocket **146** for rapidly rotating the shear roll **134** through a chain **147** and a driven sprocket **148** mounted on the shaft **135** of the shear roll **134**. The shaft **140** of the torque tube is prevented from moving relative to the pulley sprocket combination (**142,146**) by a collar **149** mounted on the extreme outboard side ot the torque tube shaft.

The shear roll is electrically biased relative to the first imaging electrode **16** in order to create better shearing effects as described in the above mentioned copending application Ser. No. 764,721 but is not shown in the drawings.

A knife edge blade **150** is next in the path of movement of the first imaging electrode **16**. This contacts the first imaging electrode when the electrode is out of imaging position. The blade **150** functions to prevent imaging suspension from traveling around the path of travel of the surface of the imagining electrode when there is no need for imaging suspension in the machine cycle. The blade is fitted in a crank arm **151** which is normally positioned to keep the blade out of contact with the first imaging electrode. The crank arm **151** is formed with two flanges **152** and **153** which contact a torque tube **154** used for moving the knife edge blade **150** against the surface of the first imaging electrode uniformly. The torque tube shaft **155** passes through suitable bearings through the side walls **119** and **120** of the first imaging electrode tank and at one end of the crank arm **156** which rotates the torque tube. The knife blade edge **150** is brought into and out of contact with the first imaging electrode surface through these connections in an operation described below.

The remaining section of the first imaging electrode tank **26** maintains the shear roll drive motor **157** mounted to the bottom plate **123** of the first imaging electrode tank and connected through a drive sprocket **158** to the timing belt **143** used to drive the shear roller **134**.

The last component interacting with the surface of the first imaging electrode **116** is a squeegee blade **159** held in a block **160** that functions to scrape off unused pigment and suspension from the first imaging electrode **16**. The block is machined down to an eccentric shaft end **161** which is held in a setting arm **162** adjusted to a predetermined pressure by a screw **163** passing through a threaded receptacle in the setting arm **162** and resting against a stop **164** mounted to the tank wall **119**. A tension spring **165** maintains the setting arm **162** in the proper position.

Reference has been made to the surface of the first imaging electrode **16**. The surface **166** is formed of a material having a resistivity of 10^7 ohms-cm. or greater that is necessary to maintain the proper electrical field conditions for imaging at the imaging zone. The surface **166** is formed of such blocking material as Tedlar, a polyvinylfluoride film, available from E.I. DuPont de Nemours & Co. or baryta paper or the like. The backing for the surface material **166** is an electrically conductive rubber-like material **167** that is capable of being deformed when contacting the injecting electrode in the imaging zone.

The same structure exist with the second imaging roller **29** which has a high resistivity surface **168** and a deformable inner core 169. Therefore, the second imaging roller 29 has an outer covering 168 of the same blocking material as the outer covering 166 of the first imaging electrode. The second imaging electrode is mounted on a shaft 170 which passes through the side wall 171 at end cap 172 and through the side wall 173 at the end cap 174. Each of the end caps maintaining the imaging electrodes are constructed with bearings so that the shafts and the electrodes thereon may be rotated freely in the end caps. The function of the second imaging electrode is to remove unwanted background particles from the image formed on the injecting electrode and to generally improve the image on the injecting electrode. It has no suspension addition function as does the first imaging electrode.

In order to best accomplish the purposes of the second imaging electrode it has been found beneficial to coat the surface with a fluid similar to, if not exactly the same as the carrier liquid of the imaging suspension. Therefore, the brushes 175 and 176 function to remove liquid from the outer surface of the second imaging electrode. The liquid is maintained in the bottom of the second imaging electrode tank 30. A wiper blade 177 is held in a mounting block 178 in contact with the surface 168 to remove the liquid therefrom. This prevents contaminated liquid from entering the imaging zone. Each of the cleaning brushes 175 and 176 have shafts 179 and 180, respectively, that pass through the side walls of the second imaging electrode cleaning tank 30. Mounted on the bottom plate 181 of the tank 30 is a motor bracket 182 housing a motor 183 which operates to turn the cleaning brushes 175 and 176.

One of the tank walls 184 has a liquid dispenser near the top thereof. The liquid used to coat the surface 168 of the second imaging electrode is squirted through a slot 185 running across the entire length of the wall 184. This permits fresh liquid to be added to the system for use with the second imaging electrode. The liquid enters the slot from the inlet 187 shown in FIG. 4.

In the operation of the imaging electrode module the carriage 28 is shuttled back and forth beneath the injecting electrode. Either the first imaging electrode 16 or the second imaging electrode 29 is thereby positioned for interfacing with the injecting electrode at station B where light rays from the object are projected. This is done by raising either the first or second imaging electrode tanks will all of the associated components therein. As shown in the figures, the tanks are shuttled by the cylinder 27 to a position where the first imaging electrode will interface with the injecting electrode when the latter is at station B along its path. The first imaging electrode tank 26 is raised up from its neutral downward position. This is accomplished by means of the cylinder 25 connected through a clevis mount to a crank arm 190 which is fixably attached to a shaft 191 maintaining an eccentric 192 thereon.

The first imaging electrode tank 26 being moved by the operation of the cylinder 25 in cooperation with the eccentric 192 is maintained for balance on a second eccentric fastened on a shaft 193 also located under the first imaging electrode tank 26. When the cylinder 25 is operated it rotates the shaft 191 through the crank arm 190. Besides lifting the tank on the eccentric 192, a chain 194 over a sprocket 195 mounted on the shaft 191 drives another sprocket 196 rotating the shaft 193 with an eccentric thereon. This double shaft-eccentric arrangement is beneficial since the tank contains heavy equipment at the one end, namely, the first imaging electrode and its associated apparatus, and heavy equipment on the other end including the shear roller motor 157. It is important to keep the tank balanced to prevent spillage of materials held within the tank and to ensure proper positioning between the first imaging electrode and the injecting electrode.

The operation of the various associated apparatus with each of the electrodes is accomplished by use of pneumatics although any other suitable mechanisms such as hydraulics, electrical or mechanical means may be used to function in a manner similar to the functioning described with the apparatus shown in this preferred embodiment.

During the operation of the machine, the first imaging electrode 16 is positioned under the imaging zone ready for operative interfacing with the injecting electrode 1. As the injecting electrode 1 moves into the contact area at station B, the cylinder 25 is actuated pulling the crank arm 190 therewith and moving the eccentrics 191 and 193 to a position where the first imaging tank 26 rests on the rise of the eccentrics. The entire tank moves upward a predetermined amount to give the proper interfacing positioning between the injecting electrode surface and the imaging electrode 16. The imaging suspension is continually supplied to the surface 166 of the first imaging electrode and the smoothing rod sends a metered amount of imaging suspension to the shear roll 134. The smoothing rod 127 is held at a predetermined pressure contact through the suspension to the electrode surface 166 by setting the torque tube shaft 131 from a crank arm 250 held in position by a spring 251.

The shear roll mechanism is actuated by bringing the roll 134 into contact with the suspension on the surface 166 of the first imaging electrode. The shear torque tube 138 is mounted on the crank arm 252 which, through the clevis mount 253 which secures it to a cylinder 254. When the cylinder 254 is actuated it causes the shear roller 134 to swing into contact with the first imaging electrode 16 through the linkages described.

The knife blade edge 150 is removed from surface contact with the imaging electrode 16 and the now applied metered and sheared suspension is moved into the imaging zone to selectively be deposited on the injecting electrode 1 in image configuration. The suspension not forming part of the image transported away on the injecting electrode 1 moves with the imaging electrode 16 into contact with the squeegee 159 held in the block 160. Here it is removed from the surface 166 before new imaging suspension is applied by the application brush 125.

After the injecting electrode 1 passes through the imaging zone, the cylinder 25 is de-energized, lowering the first image electrode tank 26. The carriage shuttling cylinder 27 is now energized pulling the carriage 28 and both the imaging tanks 26 and 30 to the right as viewed in FIGS. 1 and 3. The cylinder stops this movement when the second imaging electrode tank 30 is positioned to have the second imaging electrode 29 directly under the imaging zone.

As the injecting electrode 1 again passes the imaging zone, the second imaging electrode tank 30 is moved upward by actuating the cylinder 31 and rotating the eccentric 211 to raise the second imaging tank on the high position of that eccentric. When the second imaging electrode 29 moves in the imaging zone it has been sprayed with a fluid that is either similar to, or exactly the same as, the liquid carrier of the imaging suspension. This helps to loosen the particles that should be removed from the image held on the injecting electrode 1. Since the movement is under the same imaging conditions as existed with the first imaging electrode 16 interface, the image on the injecting electrode surface 3 is reinforced by removing the particles struck by the activating radiation from the flowing image projected from the optical system at station C.

As the second imaging electrode 29 rotates in its path of movement, the surface 168 is cleaned of all residual suspension by the action of the cleaning brushes 175 and 176. The surface is wiped clean and relatively dry by the action of the squeegee blade 177 held within the squeegee block 178. The contaminated liquid removed from the surface 168 of the second imaging electrode 29 is removed (by means not shown) from the second imaging electrode tank 30 to be filtered or in other ways processed for return through the spray system in the wall 184 of the second imaging electrode tank.

After the injecting electrode 1 passes through the imaging zone, the second electrode tank 30 is dropped to its rest position by de-activation of the cylinder 31. The cylinder 27 is once again actuated so that the tanks shuttle back to their original position where the imaging cycle may be restarted.

While the first imaging electrode **16** is not in the imaging position, that is, while the cylinder **25** is de-activated, the knife blade edge **150** is moved to contact the surface **166** of the first imaging electrode. This is done by activating the cylinder **255** moving the crank arm **156** to the right as shown in FIG. **4**.

The cylinders referred to herein may be hydraulic or pneumatic or may be replaced by electrical means such as solenoids or mechanical means such as cams. Even combinations of the above may be used for achieving the functions required to fulfill the description given herein.

The required electric potential is supplied through an electrical connector **215** and electrical contact brushes **216** which contact the shaft **116** of the first imaging electrode. (The electrical source is not shown but should be sufficient to generate between approximately 300 v. and 5,000 v. at the surface of the imaging electrodes when contacting the injecting electrode).

The apparatus around the second imaging electrode **29** is not cammed or moved in and out of contact with the second imaging electrode **29** nor is it cycle dependent as are some of the components around the first imaging electrode **16**. Both cleaning brushes **175** and **176** maintain continual contact with the surface **169** of the second imaging electrode **29**. The squeegee **177** maintains a continuous pressure contact with the surface **169** of the second imaging electrode and that pressure is predetermined by adjustment of the squeegee mount **178**. The desired pressure contact setting is achieved by positioning a crank arm **220** by turning a set screw **221** and maintaining the proper position by a tension spring **222**. The crank arm **220** is connected to the eccentric shaft **223** of the squeegee mount **178**. The shaft **179** of the cleaning brush **175** and shaft **180** of the cleaning brush **176** are mounted through bearings in each of the side walls of the second imaging tank **30**. An electrical potential is supplied to the shaft **170** of the second imaging electrode by an electrical connector **225** through electrical contact brushes **226**.

The cleaning brushes are driven by the motor **183** through a driving sprocket **230** which moves the chain **231** and the driven sprocket **232** connected to the shaft **179** of the cleaning brush **175**. Connected to a sprocket coaxial with the sprocket **232** is a chain **233** which drives the sprocket **234** turning the shaft **180** of the other cleaning brush **176**. An idler **235** maintains the chain **233** on the sprockets.

Both the imaging rollers are driven by a single chain coming off the main drive system of the machine. The chain **240** drives sprocket **241** on the first imaging electrode and sprocket **242** on the second imaging electrode such that the electrodes move in synchronism with the injecting electrode when there is contact between the two. An idler **243** maintained on the idler arm **244** ensures that the chain **240** will not slip off the sprockets **241** and **242**. Since the sprockets, like the imaging electrodes which they rotate move relative to each, this idler is beneficial in maintaining the chain over sufficient teeth of the sprocket to prevent the chain from slipping off the sprockets they drive.

While this invention has been described with reference to the structures disclosed herein and while certain theories have been expressed to explain the experimentally obtainable results obtained, it is not confined to the details set forth; and this application is intended to cover such modifications or changes as may come within the purposes of the improvements or the scope of the following claims.

What is claimed is:

1. In an apparatus for forming images by means of electrophoretic particle suspensions, including means to present activating electromagnetic radiation to the particle suspension and first and second electrodes for forming an image on one of said electrodes by exposure of suspension particles at an interface position therebetween to electromagnetic radiation and an electric field, the improvement in combination therewith including;

said second electrode being partially electrically conductive and having the surface thereof being movable through a predetermined path including the interface position with said first electrode;

a tank in which said second electrode is mounted for movement of its surface through the interface position;

applicator means for supplying the electrophoretic suspension to the second electrode surface along the predetermined path prior to the interface position, and

means to couple said second electrode to an electrical source capable of supplying an electric field between the first and second electrodes at the interface position.

2. The apparatus of claim **1** further including drive means capable of moving the surface of said second electrode past said applicator means and the interface position.

3. The apparatus of claim **1** said second electrode having operatively associated therewith cleaning means for removing residual suspension from the second electrode surface along the predetermined path downstream from the interface position.

4. The apparatus of claim **3** wherein said cleaning means includes a squeegee blade for contacting said second electrode surface.

5. The apparatus of claim **4** further including a block having said squeegee blade fitted therein and means attached to said block to move said squeegee blade relative to the surface of said second electrode surface.

6. The apparatus of claim **4** wherein said second electrode has further associated therewith a knife blade adapted for contacting the second electrode at a position along its path upstream from the interface position.

7. The apparatus of claim **6** including a torque tube to apply substantially uniform pressure between the knife blade and the second electrode surface during contact therebetween.

8. The apparatus of claim **6** further including means to move said knife blade into and out of contact with said second electrode.

9. The apparatus of claim **1** wherein said second electrode surface has operatively associated therewith shearing means adapted for applying shear forces along the path of movement of the surface upstream from the interface position.

10. The apparatus of claim **9** including means to periodically move said shearing means into and out of operable interfacing with said second electrode surface.

11. The apparatus of claim **9** including means to drive said shearing means independently of the movement of the second electrode.

12. The apparatus of claim **9** including means to apply substantially uniform pressure between said second electrode surface and said shearing means during contact therebetween.

13. The apparatus of claim **12** wherein the means to apply substantially uniform pressure includes a torque tube.

14. The apparatus of claim **1** wherein said applicator means includes

rotatable means in virtual contact with the second electrode surface to coat electrophoretic suspension materials thereon, and smoothing means to meter the materials passing between the smoothing means and the second electrode surface, said smoothing means positioned downstream from said applicator means relative to the movement of the second electrode surface.

15. The apparatus of claim **14** wherein said smoothing means is a rod.

16. The apparatus of claim **14** further including means to rotate said smoothing means into and out of operative interfacing with said second electrode surface.

17. The apparatus of claim **16** wherein said means to rotate said smoothing rod includes means to apply substantially uniform pressure between said smoothing means and said second electrode surface.

18. The apparatus of claim **17** including means to adjust the uniform pressure between said smoothing means and said second electrode.

19. The apparatus of claim **17** wherein the means to apply substantially uniform pressure includes a torque tube.

20. In apparatus for forming images by means of exposing electrophoretic particle suspensions to activating electromagnetic radiation and an electric field, the improvement in combination therewith including;

an electrode being partially electrically conductive and having the surface thereof being movable through a predetermined path adpated to interface with a member at an imaging zone;

a tank in which said electrode is mounted for movement of its surface through the imaging zone;

means to apply a liquid to the electrode surface upstream from the imaging zone;

means to clean the surface of said electrode, and

means to couple said electrode to an electrical source capable of supplying an electric field between the electrode and the member at the imaging zone.

21. The apparatus of claim 20 including drive means to move said electrode.

22. The apparatus of claim 20 wherein said means to clean includes at least one cleaning member positioned within said tank to contact the surface of said electrode.

23. The apparatus of claim 22 further including a squeegee adjustably positioned within said tank to contact the surface of said electrode downstream from said cleaning member.

24. The apparatus of claim 20 wherein said means to apply a liquid is housed in a wall of said tank having an aperture therein such that the liquid is dispensed through the aperture to the electrode surface downstream from the imaging zone position.

25. The apparatus of claim 20 wherein said electrode is cylindrically shaped.

26. The apparatus of claim 25 wherein said cylindrically shaped electrode is a roller.

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