

Oct. 12, 1954

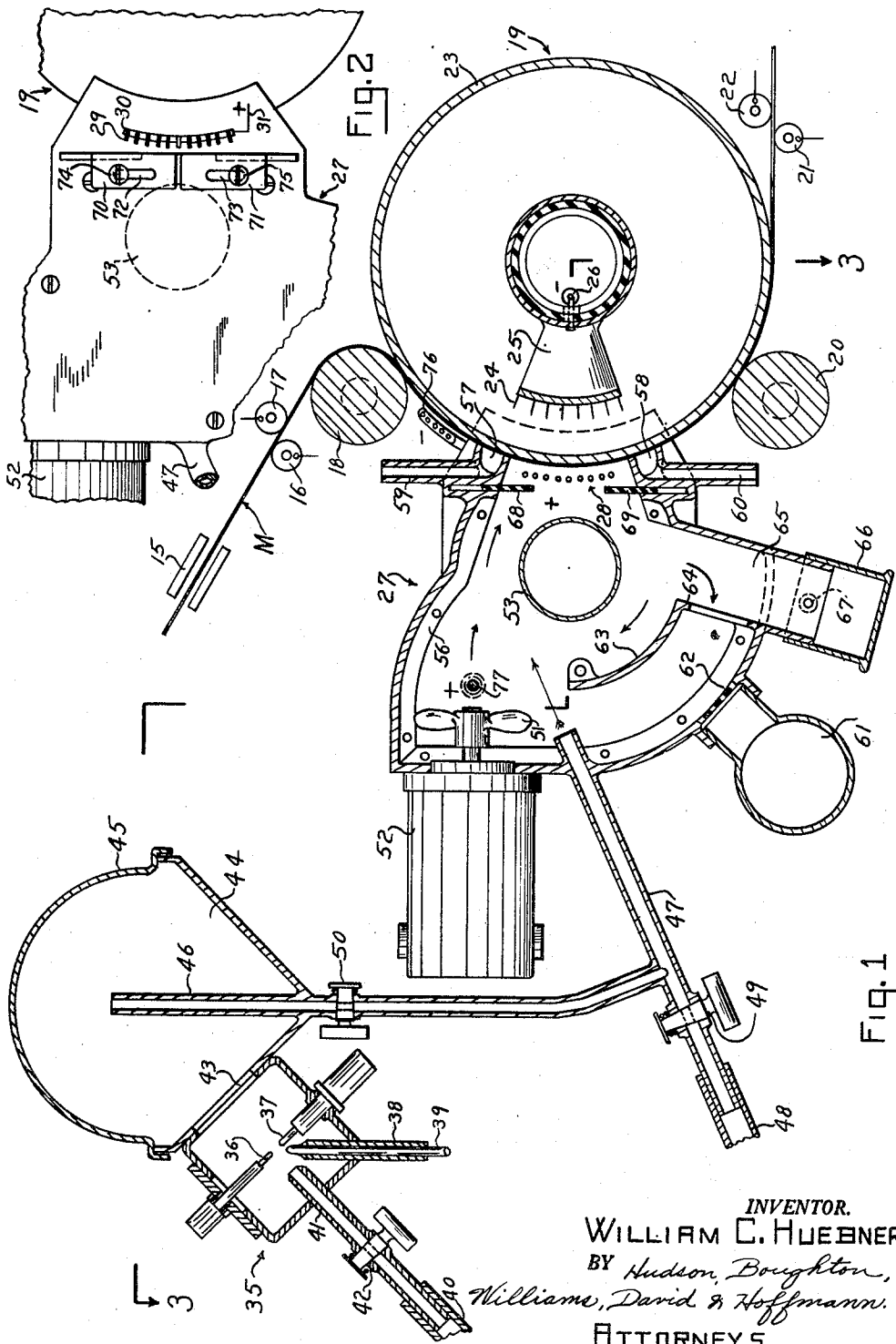
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2,691,345

COMBUSTION PRECIPITRONIC PROCESS AND APPARATUS

Filed Feb. 5, 1949

4 Sheets-Sheet 1



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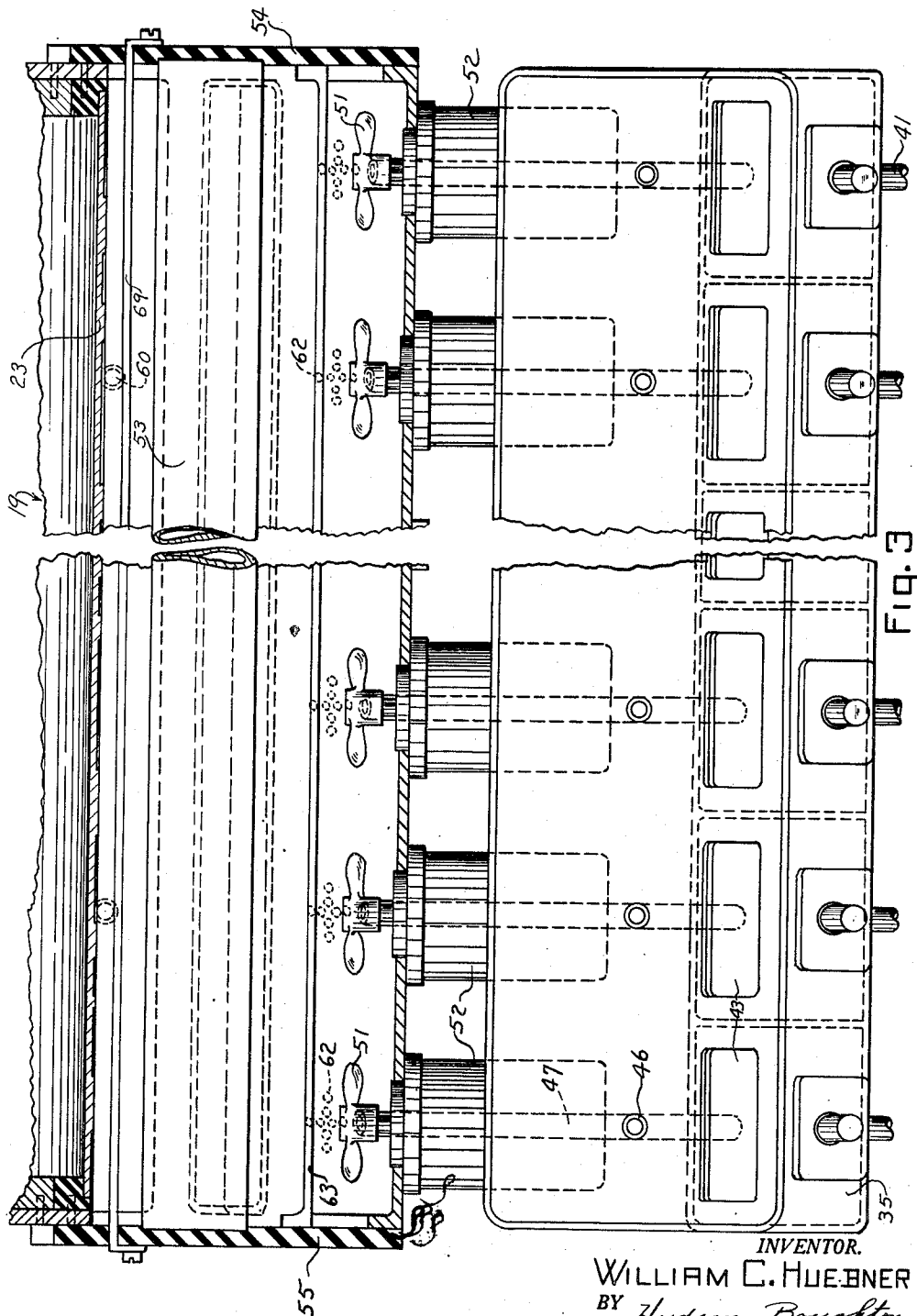
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COMBUSTION PRECIPITRONIC PROCESS AND APPARATUS

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4 Sheets-Sheet 2



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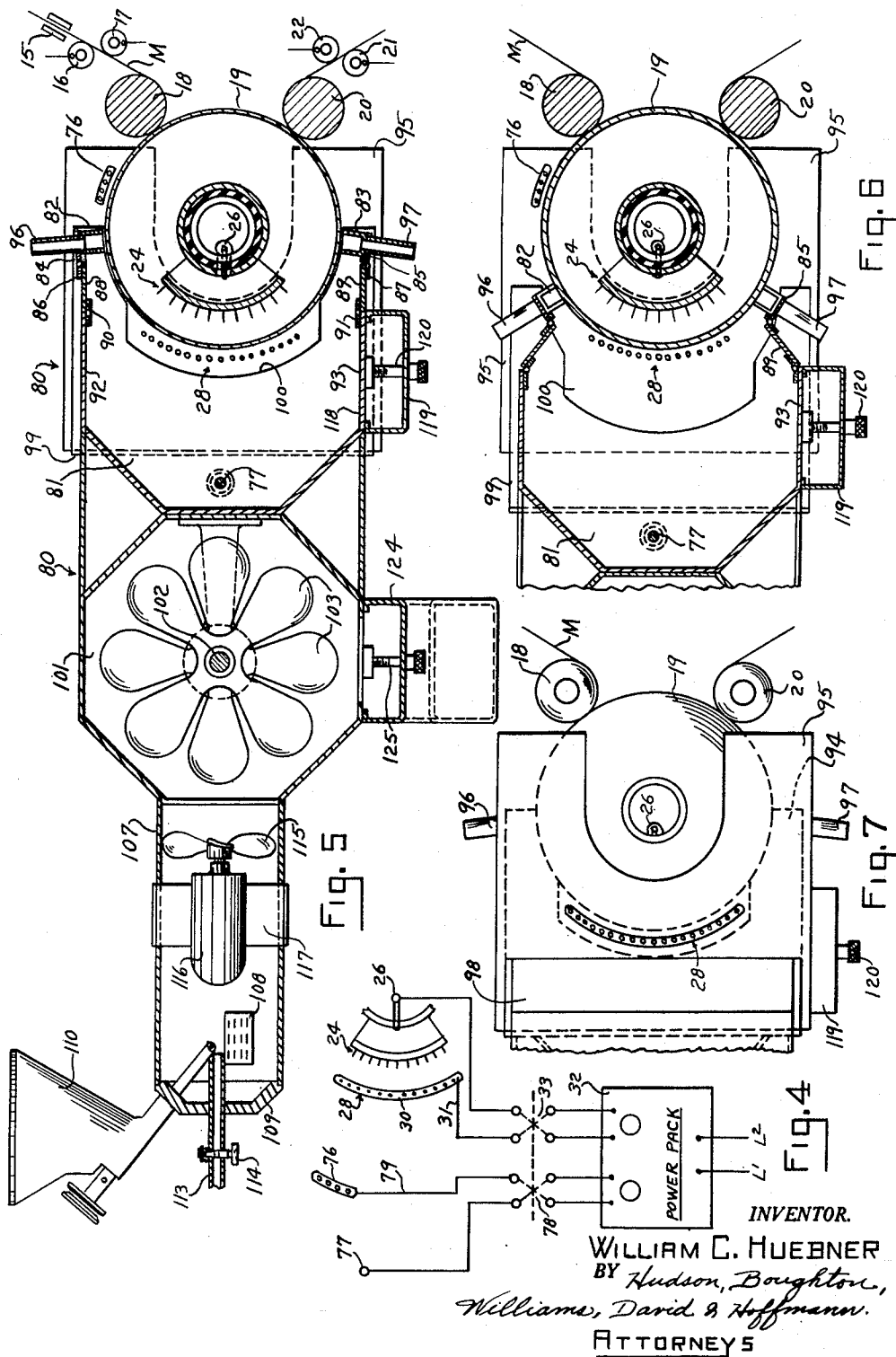
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COMBUSTION PRECIPITRONIC PROCESS AND APPARATUS

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4 Sheets-Sheet 3



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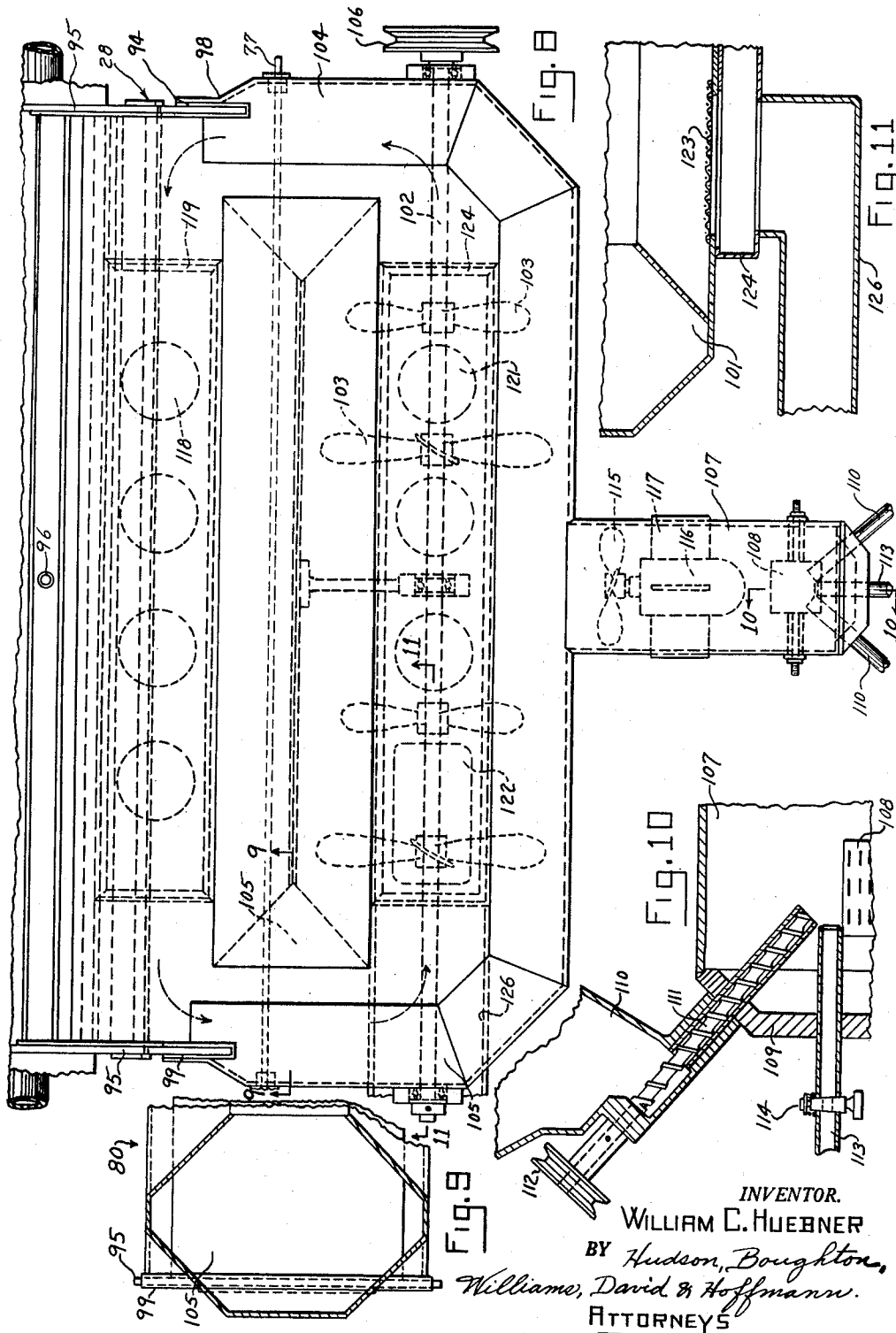
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COMBUSTION PRECIPITRONIC PROCESS AND APPARATUS

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4 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE

2,691,345

COMBUSTION PRECIPITRONIC PROCESS
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Application February 5, 1949, Serial No. 74,822

17 Claims. (Cl. 101-426)

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This invention relates to combustion precipitronic process and apparatus and, more particularly, to a novel procedure and apparatus for the reproduction of images or production of coatings by the precipitation of products of combustion upon the image receiving material under the influence of an electrical field of force, the term "combustion precipitronic" having been coined to cover these principles of image or coating formation since there is no known word or phrase in the English language which briefly and adequately identifies them.

As used in this application the word "image" is to be understood as including not only pictures, line drawings, and the like, but also text, symbols, patterns and any other configurations which may be reproduced by known printing methods. Also the term "smoke" should be understood as meaning a suspension of a solid or solids in a gas or gases and includes all finely divided material suspensions in air or other gas as a result of partial burning or combustion, whether this combustion be effected at the time of the image formation or prior thereto and then stored in suitable containers or the like for subsequent use. The term "smoke" is also to be considered as including finely-divided, fluid-suspended particles of liquid mixed with products of combustion and which may be more properly thought of as fog or the like and the term "atmosphere of smoke" refers to a region containing a gas suspension of finely-divided solids and/or minute droplets of liquid such as are present in "smoke" or "fog." The term "coating" includes a substantially uniform deposit whether the latter be in the form of a layer on the surface of a material or deposits in between the individual particles of the material.

The smoke may be in any selected color including black and/or white, depending upon the materials combusted or partly combusted, and the image or coating receiving material may be paper, cloth fabrics, or other materials which are preferably in sheet or web form. The image or coating being effected by depositing components of smoke both upon and between individual particles of the sheet or web material under the influence of an electrostatic field of force, reference hereinafter to formation of the image or coating by depositing smoke components upon the sheet or web material is intended to include both such inter-particle and surface depositing of the smoke. Finally, since the intensity and direction of an electrostatic field of force are conventionally represented by imaginary "lines of

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force," reference hereinafter to "arranging" or "interrupting" lines of force are intended to cover corresponding manipulations of the intensity of the electrostatic field of force.

5 An object of the invention is the provision of an improved method and means of forming images upon image or coating receiving material in which the image producing medium is a product or products of combustion transferred by electrical lines of force arranged in a pattern corresponding to the image, whereby smoother, denser, and more brilliant images in black, white, and/or selected color may be formed without the necessity of drying and at the same time eliminating offsetting, smudging, and other difficulties of conventional printing procedures.

10 Another object of the invention is to provide an improved procedure and apparatus in which finely divided particles are transferred to image or coating receiving material by an electrostatic field of force, the said particles being products of combustion or the like and being smaller and lighter than substances heretofore used whereby electrical potential differences of lower voltage may be employed than has been heretofore possible.

15 An additional object of the invention is to provide an improved procedure and apparatus in which products of combustion are transferred to web material by an electrostatic field of force in a manner such as to produce a substantially uniform layer or deposit upon the material.

20 A further object of the invention is to provide an improved method and apparatus for reproducing images which is especially suitable for successive depositing of colors upon the image receiving material in superimposed and juxtaposed precise register without the necessity of intermediate drying, whereby colored images may be formed in extremely short time intervals as compared with prior procedures.

25 A still further object of the invention is the provision of an improved method and apparatus for effecting coating or reproduction of images upon material by the use of products of combustion, or the like, transferred to the material by an electrostatic field of force, the procedure and apparatus being characterized by the fact that the particles employed for the coating or for reproduction of the image are driven into the structure of the image or coating receiving material and become part thereof so that they do not smudge or come off the surface of the material.

30 An additional object of the invention is the

provision of a procedure and apparatus of the type defined in any of the preceding objects and wherein heating to dry the image or coating producing medium to promote fixing, setting, or the like is eliminated, thus effecting greater economy in production and greatly reducing and/or entirely eliminating expensive drying equipment, and also providing greater safety of operation since high volatile liquids are no longer necessary.

The invention further resides in certain novel steps of procedure, features of construction and combination and arrangement of parts of apparatus, and further objects and advantages thereof will be apparent to those skilled in the art to which it pertains from the following description of the present preferred embodiment thereof, and certain modifications, described with reference to the accompanying drawings in which similar reference characters represent corresponding parts in the several views, and in which:

Fig. 1 is a transverse sectional view through the present preferred form of an apparatus constructed in accordance with this invention and operating to effect the novel procedure;

Fig. 2 is a fragmentary side elevational view of a portion of the apparatus shown in Fig. 1, illustrating the adjustment of the opening regulating means or shutters thereof and the connection of certain of the electrodes;

Fig. 3 is a fragmentary view taken substantially on the line 3—3 of Fig. 1 with certain parts shown in elevation, other parts in section, and still others removed to facilitate disclosure;

Fig. 4 is a simplified, schematic wiring diagram showing the connections to the transfer and precharge electrodes of the apparatus;

Fig. 5 is a transverse sectional view through a modified form of apparatus constructed in accordance with this invention and operating to perform the method thereof;

Fig. 6 is a fragmentary view similar to the right-hand portion of Fig. 5 but showing a portion of the cover or housing of the apparatus disposed in a different position for cooperation with a lesser segment of the circumference of the cylinder employed in the device;

Fig. 7 is a fragmentary side elevational view of the forward or right-hand portion of the device shown in Fig. 5;

Fig. 8 is a fragmentary plan view of the apparatus shown in Fig. 5;

Fig. 9 is a fragmentary sectional view taken substantially on the line 9—9 of Fig. 8;

Fig. 10 is a fragmentary sectional view to an enlarged scale taken substantially on the line 10—10 of Fig. 3 with certain parts broken away and others in section to facilitate illustration of the material feeding mechanism; and,

Fig. 11 is a fragmentary sectional view taken substantially on the section indicating line 11—11 of Fig. 8 with certain parts removed for clarity of illustration.

The principle involved in effecting image or coating formation in accordance with this invention may be briefly summarized as comprising partial burning or combustion of material or materials to produce a dense smoke, the color of which is determined by the material or materials combusted which, in turn, is selected in accordance with the color in which the image is to be formed. The smoke thus produced is caused to flow into an enclosure in which is provided the image or coating receiving material, the latter preferably providing a closure for one side of the

said enclosed space. Electrodes supplied with electrical energy of different polarity are located on opposite sides of the image or coating receiving material and, when an image is to be formed, the image to be reproduced is defined by conductive and non-conductive surfaces upon a member engaging or spaced from one side of the image receiving material and interposed between the said electrodes. Hence, the electrostatic field of force established between the electrodes, is concentrated through the portions of the image receiving material which lie in front of conductive portions of the surface on which the image is formed, and the smoke particles are transferred to and deposited upon the image receiving material by the portions of the electrostatic field acting through the said conductive portions of the image bearing surface or member. It will be appreciated that in some instances the conductive portions on the surface or member bearing the image to be reproduced may themselves constitute one electrode of the transfer electrostatic field and in such a case there need not be a separate electrode provide on the side of the said surface opposite the smoke filled enclosure. When a coating is to be formed, the electrostatic field is substantially uniform over the entire width of the material to be coated.

As mentioned above, when opposite polarity electrical energy is applied to the electrodes on the opposite sides of the image receiving material thereby producing an electrostatic field due to the potential gradient between the electrodes, the particles such as soot or the like in the smoke atmosphere within the said enclosure are attracted and transferred by the electrical field of force thereby depositing the particles upon and within the fibers of the image receiving material opposite the conductive portions on the surface bearing the image to be reproduced, none of the smoke or soot particles being deposited in the non-image areas which are represented by the non-conductive portions of the said surface. The color of the image thus formed is dependent upon the color of the smoke or products of combustion and, where multi-color image reproduction is desired, the procedure is repeated, sequentially employing products of combustion of the several selected colors, the image to be reproduced being such that the colors are selectively superimposed upon each other in the usual manner wherein ink is employed, the important difference being, however, that no drying or setting time is needed between the successive applications of different colored smoke particles in contrast with the required drying between successive application of different colors of ink. This is due to the fact that the electrostatic field of force thoroughly affixes the smoke particles to and within the image receiving material so as to become a part thereof. Moreover, since smoke is dry, the expensive heating and/or drying equipment heretofore necessary between successive stages of multi-color printing processes are eliminated, thereby greatly expediting the rate of production of the image bearing material and also reducing the cost of the equipment necessary for its production.

When a coating is to be formed, the same procedure is followed as that utilized in image formation except that the lines of force are uniformly distributed through the material and no image bearing surface is utilized.

The materials employed for the production of the smoke preferably include substances which assist the partially combusted particles such as

the soot or the like in penetrating and/or adhering to the image receiving material. That is to say, the smoke may in certain instances be somewhat oily or moist depending upon the character of the image receiving material. Where the selected materials for combustion do not per se produce a smoke of this character, the smoke-laden atmosphere may be provided with a slight amount of mist or vapor containing oily or adhesive substances in very fine droplets or colloidal suspension for mixture with the smoke prior to its transfer to the image or coating receiving material.

The present preferred form of an apparatus for effecting coating or image formation in accordance with the principles stated above is illustrated in Figs. 1 through 4. As shown therein, the apparatus is constructed in a manner permitting production of images or coating upon sheet or web material which is continuously fed through the apparatus so that successive portions of the material receive the desired coating, image or images thereon. Referring to Fig 1 the material, designated M, is shown as being fed from a suitable source of supply through a dryer 15 and thence through static eliminating devices 16 and 17 of conventional construction which may, for example, be formed and function like those disclosed in Patent No. 2,445,271, issued to William C. Huebner on July 13, 1948. The dryer 15 is of conventional construction including heating means and is employed only when the material M contains sufficient moisture to interfere with the impression thereon of electrostatic charges, there being no necessity for drying of the material to set the image or coating producing substances, i. e. the smoke, thereon. Likewise, the static eliminators need not be used in some instances, although their use is preferable to insure that the paper or other material M does not possess a static charge created through handling thereof and which would interfere with the operation of the procedure.

After passing through the static eliminators 16 and 17, the material M is then directed by an idler roller 18 onto a portion of the periphery of a cylinder 19, which carries the image or images to be reproduced, the material M continuing around the portion of the periphery of this cylinder and being held thereagainst by a second idler roller 20 and the material finally passing from the apparatus through static eliminators 21 and 22. The eliminators 21 and 22 are similar to those designated 16 and 17 and are employed for removing any electrical charge remaining upon the material M so that there will be no offsetting of the image or coating producing substance from the material M if the latter be placed in piles or rolls. The charge eliminators 21 and 22 are also preferably employed between successive stages when multicolor printing is being effected to insure that the material M, after the application of one color thereto, does not bear a charge different from that necessary for effecting transfer of the next succeeding color thereto.

The image cylinder 19 is hollow and preferably comprises a metal shell 23 which is mounted for rotation upon, and insulated from, suitable end-plates, bearings, and supporting structures constructed in a well-known manner as, for example, similar to that shown in U. S. Patent 2,408,143, issued to William C. Huebner on September 24, 1946. The metal shell 23 of this cylinder is provided with the image or images to be reproduced, this preferably being effected by photo-

graphic and electroplating procedures such as are now well known in the art, the portions of the image to be reproduced being formed as raised areas of copper with the non-image areas etched away as hollows or recesses therebetween. Within these hollows or recesses electrical insulating material is disposed, which insulating material may be of any desired type, one suitable form being that known under the trade name of "Gyptal," which is the trade name used by the General Electric Company and designates a particular class of synthetic resins made from glycerin and phthalic acid or phthalic anhydride, see U. S. Patents 1,108,329 and 1,634,969. Other suitable non-conductive substances may be employed such as resins, plastics, or the like. After the non-image areas have been filled with such material, the cylinder is preferably subjected to a light surface grinding to render the periphery thereof smooth and free from projections so as to provide a uniform surface upon the cylinder and thereby prevent injury to the image receiving material that is to move in contact therewith. The cylinder is rotated by means not shown thereby carrying the material M therewith through the apparatus. When coating is to be effected, no image is formed upon the cylinder 19 but instead the entire surface thereof is of uniform nature, for example all conductive. Since image formation is in effect a special case of coating, the hereinafter description of the apparatus as used for image formation is also applicable to coating when the cylinder 19 has no image areas.

Within the cylinder 19 is mounted a suitable electrode means which is here shown as comprising a plurality of conductive blades or projections 24 arranged in outward projecting order upon a segmental insulated support 25, the latter being non-rotatably supported upon the frame of the machine at the axis of the cylinder 19 in a manner similar to that shown in the aforementioned Patent 2,408,143. The electrodes 24 are preferably formed as blades extending substantially the entire length of the cylinder 19, the blades being connected together and to a common conductor 26 which is in turn connected with one terminal of a suitable power pack or source 32 of high potential, direct current electrical energy, see Fig. 4. In place of a plurality of radial blades 24, electrodes of other shapes may, of course, be employed in accordance with the needs of the specific type of image and/or materials utilized.

Adjacent the portion of the periphery of the cylinder 19 about which the material M passes, and opposite the electrodes 24, there is provided a housing, generally designated 27, within which smoke laden air or gas is circulated in communication with that portion of the material M which is then opposite the electrode 24. Adjacent the surface of this portion of the material M and within the housing is disposed a second electrode means, generally designated 28. The electrode means 28 preferably comprises a plurality of longitudinally extending conductive bars 29 which are mounted in insulating supports forming a part of the side wall of the housing. As shown in Fig. 2, the said bars preferably have a concave configuration coaxial with the cylinder 19 and spaced therefrom. The several bars 29 of the electrode means 28 preferably have their ends bent over the outer surface of the supporting side wall of the housing 27, the said ends being united by soldering or the like to conductive

strips such as 30. The strips 30, in turn, are connected by a wire 31 to a terminal of the previously mentioned power pack 32 which comprises a source of high potential electrical energy, the terminal connected with the wire 31 having a polarity opposite to that imparted to the wire or conductor 26.

The power pack or source 32 of electrical energy, which may be of conventional construction and supplied from alternating current supply lines L1 and L2, is preferably connected to the wires 26 and 31 through a reversing switch 33 so that the polarity of the direct current potentials applied to the electrodes 24 and 28 may be reversed in order to provide the proper direction of the potential gradient for transfer of the selected smoke employed within the housing 27. That is to say, certain materials produce products of combustion which are more readily transferred to the image receiving material when the electrical lines of force extend in one direction, while other products of combustion may be more readily transferred to the image receiving material when the electrical lines of force extend in the opposite direction. The reversing switch 33 enables the apparatus to be readily utilized with either type of material.

The smoke or other products of combustion are created, in the form of the apparatus illustrated in Figs. 1 to 3, by providing one or a plurality of combustion compartments or chambers, depending upon the size of the apparatus employed. As shown in Fig. 3, the illustrated apparatus comprises a plurality of separate combustion compartments 35 each of which is provided with carbon arc mechanism including carbon electrodes 36 and 37 supplied with suitable arcing potential and having the usual carbon feeding mechanism applied thereto for maintaining the carbons at the proper arc producing distance. Adjacent the arcing space between the carbons 36 and 37, each compartment 35 is provided with a tube 38 within which one or more sticks or cartridges 39 of the material to be combusted are placed. The sticks or cartridges of smoke producing material may be progressively fed, by any suitable means, to a point adjacent the arc so that the material of the sticks or cartridges is partially combusted, thereby producing dense smoke, the color of which is determined by the nature of the materials in the sticks or cartridges 39. In order to support this combustion, air or other combustion supporting gas is introduced at a controlled rate into each compartment 35 through a conduit 40 and a suitable nozzle 41, the latter being provided with a valve 42 for controlling the rate of introduction of the air or other gas.

The smoke produced in each of the compartments 35 flows therefrom, through an opening 43 therein, into a connected chamber 44 which is common to the several compartments 35 and receives the smoke from all of the latter so that a mixing of the smoke occurs therein. This chamber 44 is preferably provided with a removable cover 45 to facilitate cleaning and/or access to it and to the combustion chambers 35. Within the lower part of the chamber 44 and extending upwardly therein are spaced tubes 46 which may be separate members welded or otherwise secured in place, or may be formed as an integral casting with the side walls for the chamber 44. The tubes 46 extend outwardly from the chamber 44 and communicate respectively with separate nozzles 47 which are supplied with air or other

gas under pressure through conduits 48, valves such as 49 being interposed between the conduits 48 and the connections of the pipes 46 to the nozzles 47 to thereby regulate the flow of the air or other gas through the nozzles.

The flow of air or other gas through the conduits 48 and nozzles 47 has an aspirating effect upon the tubes 46 thereby withdrawing the smoke-laden atmosphere from the housing 44, the rate of this withdrawal and hence the density of the smoke being readily controlled by means of valves 50 which are interposed in the tubes 46 between the chamber 44 and the nozzles 47. In addition to the aspirating effect of the gas flow past the lower ends of the tubes 46, there is also some flow of smoke from the housing 44 due to the supply of combustion supporting gas to the chambers 35.

The nozzles 47 extend into the housing 27 at longitudinally spaced points therealong, as will be seen from Fig. 3, and the valves 49, 50 enable smoke of differing densities to be introduced through the several pipes 47 at different points within the housing 27 to effect the desired denseness of image reproduction at a desired area on the image receiving material. It will be understood that, in addition to merely regulating the density of the smoke from each of the pipes 47, some of the valves such as 49, 50 may be completely closed thereby terminating all smoke passage through the corresponding pipes 47, this being especially useful where certain areas upon the image receiving material are to receive either no or very little image reproduction.

Adjacent the inner ends of each of the tubes 47, the housing 27 is preferably provided with means for directing and moving the incoming smoke-laden atmosphere towards the image receiving material. In the present embodiment, these directing and moving means comprise individual fans or blowers 51 which are identical and are each driven by individual electrical motors 52, the latter being preferably mounted exteriorly of the housing 27. The motors 52 are preferably capable of individual energization and/or variations in speed to thereby regulate the rate of movement of the smoke-laden atmosphere forwardly towards the image receiving material in a given transverse area thereof. The housing 27 is provided substantially centrally thereof with a longitudinally extending partition member 53 which provides a somewhat circular path for the smoke-laden atmosphere from the fans to the image receiving material and thence rearwardly of the housing, this path being indicated by arrows in Fig. 1. In the present form of the mechanism, the partition member 53 is shown as being a hollow tube extending in spaced relationship with the side walls of the housing 27 and having its ends supported in sealed relationship within depressions in the end walls 54, 55 of the housing 27.

The end walls 54 and 55 of the housing 27 are preferably formed as single plates of insulating material and are fastened, as by means of screws or other suitable securing means, to integral ribs or flanges such as 56 on the edges of the housing 27. The end plates 54, 55 have a configuration corresponding substantially with that of the ends of the housing 27 except that the plates 54, 55 are somewhat wider than the housing adjacent the forward edges of the latter and these forward portions of the side plates extend on either side of the cylinder 19 and

closely adjacent the latter so as to effect a seal therewith. Preferably the forward edges of the plates 54, 55 are concave, the center of this curvature being coaxial with that of the cylinder 19 in order to provide sufficient clearance for the bearings, driving gears, and the like, of the drum.

The housing 27 is provided with longitudinally extending recesses or troughs 57 and 58 adjacent the opening in which a portion of the cylinder 19 projects. The edges of these troughs are closely adjacent the periphery of the cylinder 19 and the interiors of the recesses or troughs 57, 58 are respectively in communication with one or more conduits such as 59 and 60 which are connected to a suitable means for producing a partial vacuum. These troughs or recesses therefore constitute vacuum seals to prevent leakage of air into the housing 27 or leakage of smoke therefrom. The conduits 59, 60 are preferably connected to a main exhaust conduit 61, the latter also being connected at spaced points with the interior of the housing 27 through screened openings such as 62. An arcuate partition wall 63 extends longitudinally of the housing 27 and is spaced in front of the openings 62 to prevent the direct entrance of the smoke-laden atmosphere from the housing into the said openings. This partition 63 is spaced from the pipe 53 and, being arcuate, aids in defining an arcuate path for the smoke-laden air within the housing 27. The partition 63 has a radially extending supporting portion 64 affixed to the lower side wall of the housing or chamber 27, this radial portion being provided with openings therethrough for the admission of a portion of the smoke-laden atmosphere.

The conduit 61 is preferably connected to an exhaust such as a chimney or the like and may be provided with a suction fan or blower, if desired, it being understood, however, that the degree of vacuum applied to the conduit 61 is of a relatively low order and ordinarily is simply sufficient to maintain a balanced pressure within the housing 27, the amount of air or other gas thus removed being substantially equal to that introduced through the tubes 47. Consequently, the fans 51 can effect a continual circumferential circulation of the smoke-laden atmosphere within the housing so that a sufficient volume of smoke is maintained adjacent the electrode means 28 for effective transfer of the components or particles thereof to the image receiving material under influence of the electrostatic field of force. Since the vacuum applied to the conduit 61 is of relatively low order, the smoke-laden atmosphere will, on the average, circulate several times within the housing 27 after introduction therein before any material part of that introduced portion is withdrawn. This provides for a relatively uniformly dense volume of smoke within the housing in advance of each of the tubes 47 and fans 51, which are operating at a given time, and if all such tubes and fans be in operation, the volume of smoke circulating within the housing 27 will be of substantially uniform density. If, however, some or all of the tubes 47 and adjacent fans 51 be not in operation, there will be corresponding lighter density bands of the smoke-laden atmosphere within the housing 27. In advance of the radially extending portion 64 of the partition 63, the housing 27 has a longitudinally extending opening 65 which is formed in part by said radially extending wall or portion 64 and in part by the wall of the housing 27. This opening 65 is provided as a clean-out means

and the heavier particles of smoke, which are not readily circulated within the housing, settle through this opening into a collecting trap or cover member 66 which is provided at the outer end of the opening. The member 66 is held in place by screws or the like 67 so that the trap or clean-out cover member 66 may be readily removed for cleaning purposes.

In order to provide for selection of the extent of image reproducing action at a given time, as measured lengthwise of the material M, the housing 37 is preferably provided with movable shutter means adjacent the forward end thereof and at the rear of the electrode means 28. In the embodiment shown, the shutter means comprise a pair of movable blades 68 and 69 which are slidably supported in slots or recesses of the housing 27 for movement towards or away from each other. The said blades or shutters extend longitudinally of the housing and their outer ends extend through slots in the endplates 54, 55. The ends of these blades or shutters 68, 69 are shown as provided with right-angle flanges, such as 70 and 71, respectively, which have a sliding engagement with the outer surfaces of the endplates 54 and 55. These flanges 70, 71 each have an elongated slot, such as 72 and 73, therein through which extend clamping screws 74 and 75, respectively. The screws are threaded into the endplates 54, 55 and the construction is such that, when the screws 74, 75 are loosened, the shutters or blades 68, 69 may be moved within their slots by means of their flanges and then clamped in an adjusted position by again tightening the screws 74, 75. The flanges 70 and 71 are preferably of such length that they overlie the open ends of the slots in which the blades 68 and 69 slide when the said blades are in their outermost or retracted positions, thereby sealing these openings and preventing escape of the smoke-laden atmosphere therethrough. It will be understood that, when the blades or shutters 68, 69 are at their innermost positions, substantially as shown in Figs. 1 and 2, the smoke in the housing cannot enter the slots and hence there is no escape of smoke from the ends of the slots even though the flanges 70 and 71 do not overlay them at that time.

It is frequently advantageous to provide a precharge for the image receiving material M and also for the smoke in the housing 27. For the purpose of precharging the material M, electrode means 76 is mounted adjacent the material at a location intermediate the idler 18 and the housing 27. The precharge for the smoke is provided by a wire or rod 77 extending longitudinally of the housing 27 adjacent the fans 51. The electrode 77 is insulated from the housing and is connected to the power pack 32 through a reversing switch 78. The electrode means 76 is also connected to the power pack 32 through a reversing switch, this connection being made in the illustrated embodiment by a wire 79 connecting the electrode means to one-half of the double pole switch 78. The electrical potentials applied to the precharge electrodes 76 and 77 are of lower values than are applied to the transfer electrodes 24 and 28, the former preferably being in the order of one-half the latter. The polarity of the potential applied to the electrode 76 should always be the same as that applied to the electrode 24 and the potential applied to the electrode 77 should be the same as that applied to the electrode 28. Therefore, the reversing switches 33 and 73 are preferably ganged together for si-

multaneous operation, as is indicated in Fig. 4.

In operation of the apparatus shown in Figs. 1 through 3, the sheet material M upon which images are to be reproduced is threaded through the drier 15, if the latter be used, then between the static eliminators 16, 17 to the idler roller 18. The material is then carried partially about the roller 18 and threaded between the housing 27 and a portion of the image cylinder 19, and thence between the cylinder and the idler 20. After passing between the cylinder 19 and the roller 20, the material M is passed through static eliminators 21, 22 to either a correspondingly constructed apparatus, if a multicolor process be employed, or to suitable mechanism for winding, severing, or otherwise handling the completed material, if but a single color process is utilized thereon. The cylinder 19 will, of course, have been prepared so that its surface is provided with electrically conductive portions corresponding with the image to be reproduced, the non-image areas having insulating material thereon so that electrical lines of force can extend only through the image areas and do not extend through the non-image areas.

The material from which the smoke is to be formed is selected in accordance with the particular color utilized and is introduced into the tube 38. The electrical arc is then established between the electrodes 36, 37 and air or other suitable combustion supporting gas is introduced through the conduit 40 at a regulated rate as determined by the setting of the valve 42. When each of the combustion chambers 35 has thus been placed in operation, the valves 49 and 50 are adjusted to produce the desired density of smoke flowing into the chamber 27 and some or all of the motors 52 are placed in operation. All of the motors 52 are energized when a uniform density of smoke is desired within the housing 27, only selected ones of the motors 52 being energized when bands of lighter and denser smoke are desired in the housing. The shutters or blades 68, 69 will have been adjusted to provide a desired opening therebetween thereby regulating the longitudinal portion of the material M which is to have the image reproduced thereon at a given instant of time, this being determined in accordance with the diameter of the image cylinder, the nature and shape of the electrodes, such as 24, 28 employed therewith, the type of image being produced, the nature of the material, etc. The shutters 68, 69 also regulate the density of the image formed to a certain extent, since a narrower opening will generally provide a more dense deposit than will a wider opening.

With the apparatus thus set up, electrical potentials of opposite polarity are applied to the electrodes 24 and 28 from the power pack 32, the switch 33 being positioned so that the respective polarities are proper for the nature of the smoke employed. The potential difference between the electrodes 28, 24 creates an electrostatic field which causes the smoke particles or components to move towards and be deposited upon the image receiving material. It will be understood that the lines of force or intensity of the electrostatic field are concentrated opposite those conductive portions of the cylinder 19 positioned between the electrodes 24, 28 so that the movement and depositing of the smoke particles occurs only opposite such conductive portions of the cylinder 19 and does not occur opposite the non-conductive portions. Since the cylinder 19 is rotated and carries the material M therewith, the vari-

ous conductive and non-conductive portions of the cylinder sequentially pass between the electrodes 24, 28 with the result that the image upon the cylinder is progressively formed upon the image receiving material. In addition to the other controls mentioned, such as valves 42, 49, 50, motors 52 and shutters 68, 69, the speed of the cylinder 19 and the value of the potential difference between the electrodes 24 and 28 will also affect the density of the deposit of smoke in the form of an image upon the image receiving material. Hence, by selecting suitable values for these and the other variables, images of any desired density may be formed.

As mentioned heretofore, the material M may be dried, as by means of a heating type drier 15, to drive off moisture in the material if the latter should contain a sufficient quantity thereof to interfere with the reproduction process as, for example, when the climatic conditions are relatively humid. The static eliminators 16, 17 remove any charges that may arise or be imparted to the material due to the handling thereof and after such stray charge removal the material is preferably provided with a precharge prior to its introduction into the image producing zone by means of the precharge electrodes 76. This precharge is of predetermined amount and is of the same polarity as that upon the electrode 24. Also the smoke-laden atmosphere in the housing 27 is preferably precharged by the rod or wire 77 which has the same polarity as that of the electrode 28.

This precharging of the material M and of the smoke circulating within the housing 27 facilitates the depositing of the smoke particles in image areas upon the material M by the electrostatic field as the material moves past the opening of the housing 27. This transfer of the particles, such as soot or the like, by the electrostatic field causes the particles to be deposited not only upon the surface of the material M but also in the spaces between the fibres or pores thereof so as to form an integral part of the material. Hence, the resulting image cannot be removed by rubbing and does not smudge as would normally be expected of smoke particles which are simply deposited upon the surface of the material.

The material thus provided with an image in a selected color, then passes through the charge or static eliminators 21, 22 to remove any electrical charge remaining thereon. If a multicolor image is desired, the material may then be passed sequentially through similar apparatus in each of which the combusted material 39 is of a type to provide the desired next color applied to the material, the procedure being repeated for each selected color to be utilized, as is well known in the printing art. An important difference is to be noted, however, in that when employing the procedure and apparatus of this invention, it is not necessary to dry the material between color applications and before it is introduced into the next succeeding apparatus for imparting a different color thereto, thereby eliminating expensive equipment, removing dangers of fire or other hazards, and greatly decreasing the cost of the equipment. Furthermore, since the particles of smoke, which are employed in formation of the image are generally microscopic in size, the resulting image is much sharper in outline and can be denser and more uniformly colored than when printing or image formation is effected by other known processes, these differ-

ences being readily apparent to the eye but being especially obvious under magnification.

The procedure of this invention may likewise be performed by means of an apparatus constructed in a manner similar to that illustrated in Figs. 5 through 11. In this form of the apparatus, the material M is led about an image receiving cylinder 19 which is constructed in a similar manner to the cylinder 19 of the previously described form of the apparatus and functions in the same manner. The material M is maintained in contact with the surface of the cylinder 19, to be carried thereby through the image producing zone, by idler rolls 18 and 20 which are identical with those previously described but are positioned at slightly different points about the periphery of the cylinder 19 due to the different shape of the apparatus. Likewise, the instant form of the apparatus may employ a heater type drier, such as 15, static eliminators 16 and 17, and a precharge electrode 16 for the material M prior to its introduction into the image producing zone. Also, charge eliminators such as 21, 22 may be utilized adjacent the material M as it proceeds from the image producing zone to thereby remove any electrical charges remaining upon the material.

In the instant form of the apparatus the cylinder 19 is rotatably mounted adjacent an opening of a housing, generally designated 89. This housing is preferably formed of a plurality of hollow portions each of which is preferably polygonal in cross section with the several portions connected to provide a closed circulating path for smoke or the like. Thus, the housing has longitudinal portions extending parallel with each other and parallel with the axis of the cylinder, the two portions being separated from each other along their length by a closed wall but communicating at the ends through a corresponding polygonally-shaped connected end portion, see Figs. 5 and 8. The forward channel or portion 81 of the housing 80 is that which cooperates with the image cylinder 19 and therefore the outer longitudinal side of this portion of the housing is open, the space thus provided being filled by the cylinder 19 and by longitudinally extending exhaust channel members 82 and 83 extending the entire length of the cylinder. These members 82, 83 are each mounted upon similar longitudinally extending plates 84, 85, respectively, which plates are pivoted by hinges 86, 87 to plate members 88, 89 respectively. The plate members 88, 89 are in turn pivoted by hinges 90, 91 to the top and bottom plates 92, 93 of the channel or portion 81 for the housing 80. The ends of this portion 81 of the housing are formed, in part, by forwardly extending plate members 94, 95 which extend closely adjacent the ends of the cylinder 19 in overlapping relationship thereto, the plate members having centrally disposed forwardly directed openings within which the bearings and/or a portion of the driving means for the cylinder 19 are freely received. The portions of the plate members 94, 95 on either side of the central openings extend adjacent the periphery of the cylinder 19 and prevent the escape of the smoke-laden atmosphere from the housing 80 at this point. Any smoke which tends to escape between the plate members 94, 95 and longitudinally of the cylinder 19 is collected in the channels or troughs 82, 83 and conducted therefrom through the conduits 96, 97 which are connected to a suitable chimney or means for providing a partial vacuum.

The plate members 94, 95 are formed of insulating material and are stationarily mounted, for example upon the supporting frame for the cylinder 19, the plate members being slidable within guide members 98, 99 which are substantially U-shaped in section, with one leg thereof longer than the other, this longer leg being disposed adjacent the inner side of the plates as will be apparent from Figs. 7 and 8. The plates 94, 95 also provide the mounting for the ends of the bars forming the electrode 28, the latter being mounted in substantially the same manner as described with respect to Figs. 1 and 2. Consequently, the inner leg of each of the members 98, 99 has a recess which includes a substantially arcuate portion, such as indicated at 100 in Figs. 5 and 6, so as to clear the electrode 28. Both legs of the members 98, 99 have sufficient length so that the entire housing 80 may be moved away from the cylinder 19, or to the left as shown in Figs. 5 and 6 from the position indicated in the former figure to a position similar to that indicated in the latter figure, this movement being effected without, however, interrupting the seal provided by the plates 94, 95 within the members 98, 99 carried by the housing. This adjustment is provided for the purpose of enabling cylinders 19 of different diameters to be utilized and/or to employ different areas of image reproduction on a given cylinder, the hinging of the exhaust channels or members 82, 83 enabling the latter to be maintained in close proximity to the cylinder 19 even when the housing has been moved rearwardly as is indicated in Fig. 6.

The rear branch or portion 101 of the housing 80 has a shaft 102 extending longitudinally therethrough on which are supported fans or impellers, such as 103, for moving the smoke-laden atmosphere through the housing portions 101 and the connecting end portion 104 into the forward portion or branch 81 and thence back through the other connecting end portion 105, as indicated by the circulation arrows in Fig. 8. This provides an endless path for the smoke-laden atmosphere which is introduced into the portion or branch 101 in a manner about to be described. The shaft 102 may be rotated by any suitable means and for this purpose the shaft is shown as journaled in suitable bearings carried by the housing 80 with one end of the shaft being provided with a pulley 106 exteriorly of the housing to which a belt from a suitable motor or the like may be connected.

The smoke-laden atmosphere, which is employed for the image reproduction and which is introduced into the housing 80, may be provided by means similar to that shown in Figs. 1 through 3. In the instant form of the device, however, a somewhat different form of combustion means is provided and which can be utilized for employing powdered material without having the latter in stick or cartridge form. As will be seen from Figs. 5, 8, and 10, the portion or branch 101 of the housing 80 is provided substantially centrally thereof with a connecting chamber formed in a housing or conduit member 107 and this chamber or housing is provided adjacent the rear thereof with a suitable heater such as an electric resistance heater 108. Supported upon the rear of the housing 107 by suitable bracket or support means 109 are a plurality of hoppers 110 for containing the smoke producing material. These hoppers each preferably converge towards a bottom outlet in which is journaled a feeding screw such as 111 that may be rotated by any suitable

means. In the present form of the device, each of the screws 111 is shown as provided with an outwardly extending shaft portion on which is mounted a pulley 112 so that the feed screws 111 may be rotated individually or jointly either by hand or by suitable mechanism connected with the pulleys. The screws 111 may, if desired, be used alternatively or in predetermined timed relation with each other depending upon the type of material employed to produce a smoke of the desired characteristics. For example, one hopper may contain a material productive of one color, while the other hopper may contain a material productive of a different colored smoke, the exact color produced being dependent upon the relative amounts of the two materials fed from each of the hoppers in a given interval of time. The material fed from each hopper falls upon the upper surface of the heater 108 and is there subjected to combustion supporting gas or gases such as air or the like which are introduced into the housing 107 through a tube 113 so that the material from the hoppers is partly combusted or burned to produce the previously mentioned smoke. The tube 113 may be provided with any suitable means for controlling the flow of air or other fluid there-through, such as a suitable valve 114 similar to those indicated at 42 in Fig. 1.

The smoke thus produced within the housing 107 is moved through the latter and into the housing 80 by means of a fan or impeller 115 which is supported and rotated within the housing 107 by a suitable motor 116, the latter being mounted by radially directed brackets such as 117 which freely permit the flow of smoke therepast. The smoke-laden atmosphere entering the branch 101 of the housing 80 is circulated through the latter and the portions 104, 81 and 105 of the housing in a closed path, as previously mentioned, so that the smoke passes adjacent the electrode 28 over the entire length of the cylinder 19. Therefore, the application of electrical potential between the electrodes 24 and 28 acts, as in the previously described embodiment, to produce an electrostatic field of force extending through the conductive portions of the cylinder 19 causing smoke-laden particles to be transferred to the image receiving material M in configurations corresponding with the image upon the cylinder 19, the operation in this respect being the same as that previously described.

The lower portion of the branch 81 of the housing 80 has a plurality of spaced openings 118 in the lower wall thereof and a receptacle 119 is attached to this lower wall of the housing so as to close the openings 118 and provide a clean-out trap, the receptacle being held in place by a plurality of screws such as 120. Hence, any heavy particles of the smoke which cannot be readily circulated through the portion 81 of the housing 80 settle into the receptacle 119 and are periodically removed by removal of the member 119.

The branch 101 of the housing 80 is likewise provided with a plurality of openings 121 which are similar to the openings 118. In addition, the lower portion of this branch of the housing is provided, adjacent the end portion 105, with an enlarged rectangular opening 122, the latter preferably having a screen or foraminous covering 123 thereover. Below the openings 121, 122 is provided a receptacle 124 which is removably secured to the housing 80 by screws or the like 125 in the same manner as the receptacle 119 thereby enabling the receptacle to be readily removed to clean the latter of relatively heavy particles

which settle therein through the openings 121. The receptacle 124 differs somewhat, however, from the receptacle 119 in that the former is provided with an exhaust conduit connection 126 which is connected to the receptacle and communicates with the interior thereof substantially below the screened opening 122. The previously mentioned exhaust conduits 96, 97, connected with the channels or trough 82, 83 cooperating with the cylinder 19, are preferably connected with the exhaust conduit or duct 126 and the latter is led to a suitable chimney or exhaust means which may employ a suction fan or the like, not shown. The partial vacuum or suction applied to the conduit 126 is preferably such that the smoke-laden atmosphere introduced into the housing 80 is normally allowed to circulate a plurality of times in a closed path before any appreciable part thereof is withdrawn through the screened opening 122, the amount of gas removed from the housing 80 being substantially equal to the volume which is introduced into the housing due to the introduction of air or the like into the housing 107 to support the combustion therein. This latter quantity of air may, as previously mentioned, be controlled by the valve 114 and also by the speed of rotation of the motor 116 which drives the fan 115. The speed of circulation of the smoke-laden atmosphere within the housing may be controlled by the speed at which the shaft 102 is driven so that the desired degree of stirring of the smoke-laden atmosphere is produced to give the prerequisite density.

The electrodes 24 and 28 are connected to a suitable source 32 of direct current electrical potential through a reversing switch 33, see Fig. 4, in the same manner as are the corresponding electrodes in the form of the device shown in Fig. 1. Likewise, the precharge electrode 76 for the material M, which preferably is supported by the plates 94, 95, is connected to the power pack through a second reversing switch 78, as in the previously described form of the apparatus, and a precharge potential may also be connected to a precharge electrode 77 located within the branch 81 of the housing 80 and extending longitudinally thereof. As in the previous form of the apparatus, the polarity of the potential applied to the electrode 24 is the same as that applied to the precharge electrode 76 and the polarity applied to the electrode 28 is the same as that applied to the electrode 77. These polarities may, however, need to be reversed for certain types of smoke producing material and/or image receiving material and this as well as the corresponding necessary reversal of the precharge potential polarities can be easily effected by the reversing switches 33 and 78.

The operation of an apparatus constructed as just described is in accordance with the previously mentioned principles and hence need not be set forth here in detail. Suffice it to note that the material upon which the image is to be reproduced is led through the machine by the image carrying cylinder 19 in intimate contact with the latter as in the previous form of the apparatus, the material being dried, if necessary, and the static charges thereon removed, as previously described. The housing 80 is adjusted towards or away from the cylinder 19 depending upon the diameter of the latter and/or the desired segmental portion thereof to be utilized in the operation, this adjustment being effected by moving the entire housing 80 relative to the cylinder 19. In all relative positions of the housing and

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cylinder, however, a seal is maintained at the end of the chamber 80 by virtue of the sliding of the plates 94, 95 within the members 98, 99, the upper and lower portions of the housing hinging, as indicated in Figs. 5 and 6, to enable the troughs or channels 82, 83 to cooperate with the particular cylinder or segment thereof employed.

The material which is used to form the smoke is introduced into the hoppers 110 and the heater 108 is provided with electrical energy to heat the latter to the desired temperature for partial combustion of the materials fed from the hoppers 110 by rotation of the screws 111. The density of the smoke produced is a function both of the rate of feeding of the material and of the supply of combustion supporting gas such as air through the pipe 113. The supply of the gas, such as air, may be controlled both by regulation of the valve 114 and by the speed of rotation of the motor 116 so that a smoke of desired volume and density is procured. This smoke is circulated within the housing 80 by the fans 103 so that smoke is brought adjacent the entire width of the material M over the length of the cylinder 19 for transfer of the particles of the smoke to the material M and imbedding therein at the areas representing the image portions of the cylinder and at which electrostatic lines of force are established between the electrodes 24 and 28.

It will be apparent that the chief difference in the operation of this form of the device over that shown in Figs. 1 to 3 resides in the manner in which the smoke is produced and also in the fact that, in the instant case, the smoke is circulated parallel with the axis of the cylinder, whereas in the form of the apparatus shown in Figs. 1 to 3, the smoke is circulated in a cylindrical path, the axis of which is parallel with the axis of the cylinder so that the individual smoke particles circulate in paths at right angles to the axis of the cylinder. Otherwise, the operation of the two forms of the apparatus is substantially the same and hence the operation of this embodiment need not be further described, it being noted, however, that this form of the apparatus may likewise be employed for multicolor operations by utilizing a plurality of devices operating sequentially upon the image receiving material, as previously described.

In place of employing the smoke producing means shown in either Figs. 1 or 5, 8 and 10, the smoke may be produced by similar or any other suitable means at a point remote from the smoke transferring apparatus and stored in suitable containers from which it is then introduced into either the housing 27 of the apparatus shown in Figs. 1 to 3, or into the housing 80 shown in Figs. 5 to 11, thereby eliminating the separate combustion means illustrated. When utilizing certain types of smoke producing material and/or when the image receiving material has surface characteristics or porosities such as not to readily allow imbedding of the smoke particles, adhesive or oily materials may be introduced into the smoke-laden atmosphere in the form of very fine vapor or mist for circulation with the smoke. This may, for example, be effected by attaching suitable vapor supplying means to the tubes 48 or 113, respectively, of the two forms of the apparatus. As mentioned heretofore, the apparatus and procedure may also be used to produce a coating or deposit upon web material by simply not providing an image upon the cylinder 19 so that the electrostatic field is uniform throughout the width of the material. Other variations and

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adaptations of the method and apparatus of this invention may be readily devised by those skilled in the printing and associated arts after having had the advantage of this disclosure and, consequently, the specific steps of procedure and details of construction herein illustrated and described are to be considered simply as illustrative of the invention and not as limitations thereof.

Having thus described the invention, I claim:

1. The method of producing an image upon image receiving material which comprises creating an electrostatic field of force extending through the said material with the lines of force of said field arranged in accordance with the configuration of the image to be produced, creating smoke by combustion of a smoke producing substance at a region remote from said field of force, and conducting the smoke into the region of influence of said field of force adjacent that surface of the said material on which the image is to be produced while the material is in said field, thereby causing the solid particles of said smoke to be deposited upon the image receiving material by the said lines of force.
2. The method as defined in claim 1 and further comprising controlling the volume of combustion supporting gas supplied to said smoke producing material while combusting the latter thereby regulating the density of the said smoke.
3. The method of producing an image in color upon image receiving material which comprises creating an electrostatic field of force extending transversely through the said material with the lines of force of said field arranged in accordance with the configuration of the image to be produced, providing a plurality of quantities of opaque products of combustion in the form of smoke each having a different color, mixing selected ones of said quantities of smoke to produce a color corresponding with that in which the image is to be produced, and supplying the mixed smoke into the region of influence of said field of force adjacent that surface of the said material on which the image is to be produced, thereby causing the solid portion of said smoke to be deposited upon the image receiving material by the said lines of force.
4. An apparatus for repeatedly producing an image upon a web of image receiving material comprising a housing having an elongated opening in one side thereof, a hollow rotatable image cylinder supported adjacent said housing with a portion of the surface of said cylinder positioned within said opening and substantially closing the latter, means to adjust the effective area of said opening, the surface of the cylinder including conductive image portions and non-conductive portions representing non-image areas, electrode means stationarily supported within said cylinder, electrode means supported in said housing adjacent the surface of said cylinder but spaced therefrom, means causing the image receiving material to move in timed relationship with said cylinder in a path extending between the surface of said cylinder and the said electrode means within said housing when the said cylinder is rotated, means for supplying smoke to said housing thereby creating an atmosphere of smoke about the electrode means in said housing, and means for supplying electrical energy of opposite polarity to said electrode means for creating an electrostatic field of force therebetween through which the image receiving material and the surface of said cylinder move whereby the image is progressively sequentially formed by the deposit-

ing of smoke components upon the moving material under the influence of the said electrostatic field the lines of force of which are sequentially arranged in accordance with successive portions of such image by the passage of the said conductive and non-conductive portions of said surface through the said field.

5. An apparatus as defined in claim 4 and in which the means to adjust the effective area of the opening in said housing comprise shutter means supported by said housing adjacent said opening for movement transversely of said opening.

6. An apparatus as defined in claim 4 and in which the said housing is movable towards and away from said cylinder and the said means to adjust the effective area of the said opening comprise hingedly connected members extending longitudinally of said housing as extensions thereof and adapted to be moved relative to each other and generally transversely of said opening.

7. An apparatus for repeatedly producing an image upon a web of image receiving material comprising a housing having an opening in one side thereof, a hollow rotatable image cylinder supported adjacent said housing with a portion of the surface of said cylinder positioned within said opening and substantially closing the latter, the surface of the cylinder including conductive image portions and non-conductive portions representing non-image areas, electrode means stationarily supported within said cylinder, electrode means supported in said housing adjacent the surface of said cylinder but spaced therefrom, means for causing the image receiving material to move in timed relationship with said cylinder in a path extending between the surface of said cylinder and the said electrode means within said housing when the said cylinder is rotated, means for creating products of combustion in communication with said housing for providing an atmosphere of said products in the form of smoke in said housing, and means for supplying electrical energy of opposite polarity to said electrode means for creating an electrostatic field of force therebetween through which the web material and the surface of said cylinder move whereby the image is progressively sequentially formed by the depositing of opaque smoke components upon the moving material under the influence of the said electrostatic field the lines of force of which are sequentially arranged in accordance with successive portions of such image by the passage of the said conductive and non-conductive portions of said surface through the said field.

8. An apparatus as defined in claim 7 and wherein the said smoke creating means include a heat producing means, means for supplying smoke producing means to said heating means and means for supplying combustion supporting gas at a controlled rate.

9. An apparatus as defined in claim 7 and wherein the said smoke creating means include separate supply containers for different combustible materials productive of different colors of smoke, heating means, and separate feeding means for each of said containers to effect controlled delivery of smoke producing material to the said heating means.

10. An apparatus as defined in claim 7 and wherein the said smoke creating means include a plurality of separate combustion chambers,

means in each of said chambers for producing smoke by partial combustion of smoke producing material, and means for conducting the smoke from said chambers to spaced points in said housing.

11. An apparatus as defined in claim 7 and further comprising means for circulating the smoke including fan means positioned within said housing to circulate the said smoke in a substantially closed path therein.

12. An apparatus as defined in claim 7 and further comprising means for circulating the smoke including fan means positioned within said housing and directed to circulate the said smoke in a substantially closed path the axis of which extends substantially parallel with the axis of said cylinder.

13. An apparatus as defined in claim 7 and further comprising means for circulating the smoke including a plurality of fans mounted within said housing with their axes directed transversely of the axis of said cylinder and a separate motor for driving each fan whereby the circulation of the smoke adjacent different areas of the portion of the image receiving material within the housing may be varied.

14. An apparatus as defined in claim 7 and further comprising means for circulating the smoke including fan means within said housing disposed with the axis thereof extending substantially parallel with the said opening whereby the smoke is circulated adjacent the said image receiving material in a path extending transversely of the direction of movement of the material.

15. An apparatus as defined in claim 7 and wherein the said housing is provided with means for removing a portion of the smoke from said housing after circulation therethrough.

16. An apparatus as defined in claim 7 and further comprising means for applying a partial vacuum adjacent the edges of said opening which extend longitudinally of said cylinder to prevent escape of smoke from said housing and entrance of air therein.

17. An apparatus as defined in claim 7 and further comprising means to regulate the density of the smoke supplied to said housing.

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