

Feb. 8, 1955

C. F. CARLSON

2,701,764

ELECTROPHOTOGRAPHIC APPARATUS AND METHODS

Filed May 2, 1951

4 Sheets-Sheet 1

FIG. 1

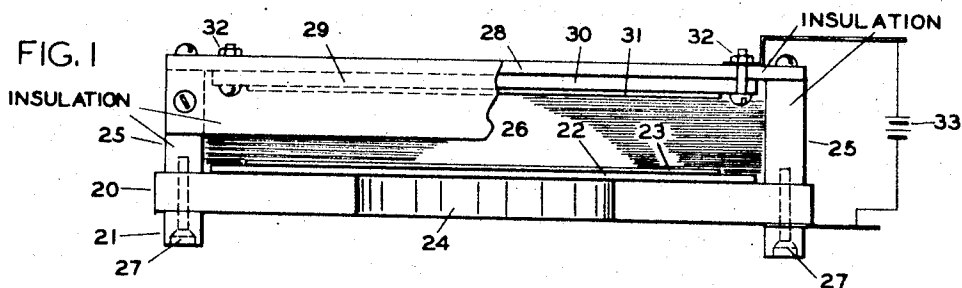


FIG. 2

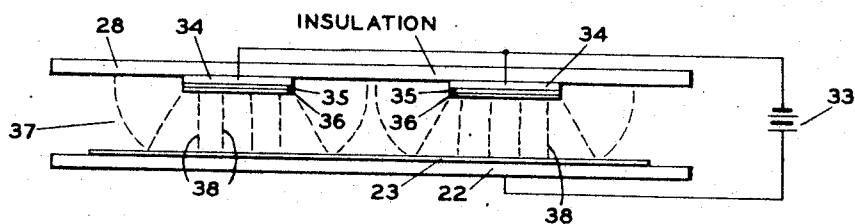


FIG. 3

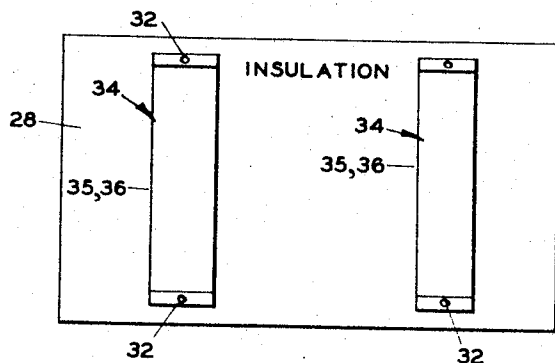


FIG. 4

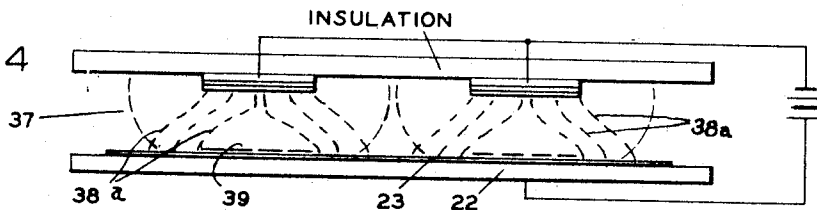
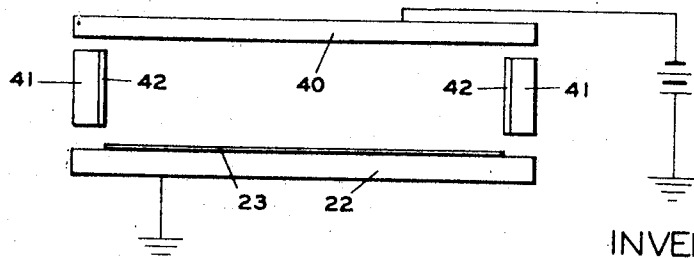


FIG. 5



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FIG. 6

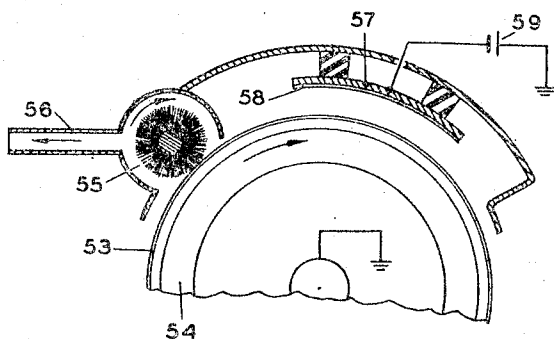


FIG. 7

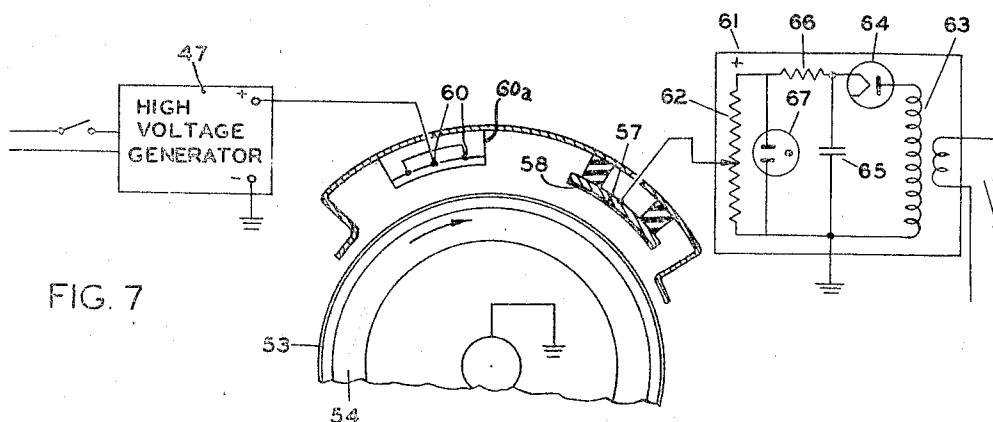
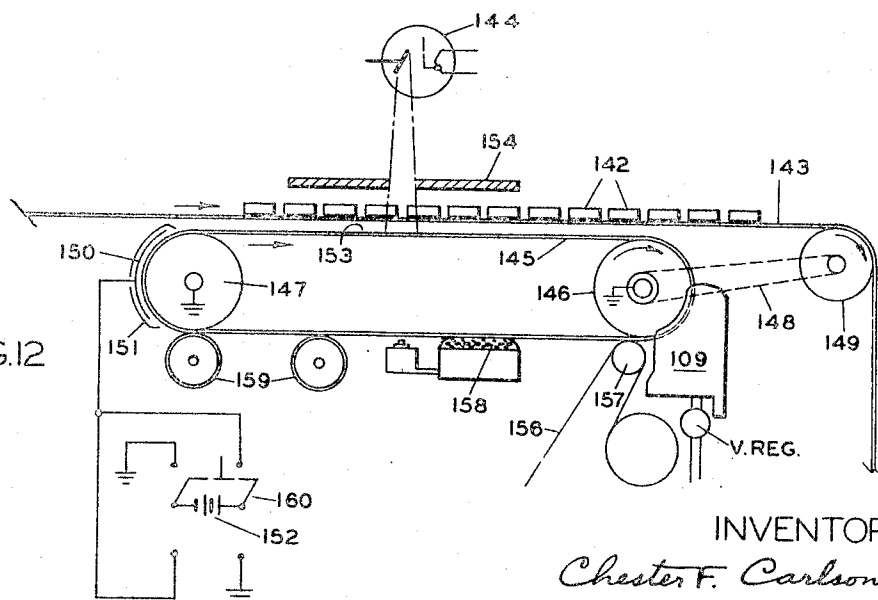


FIG. 12



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FIG. 8

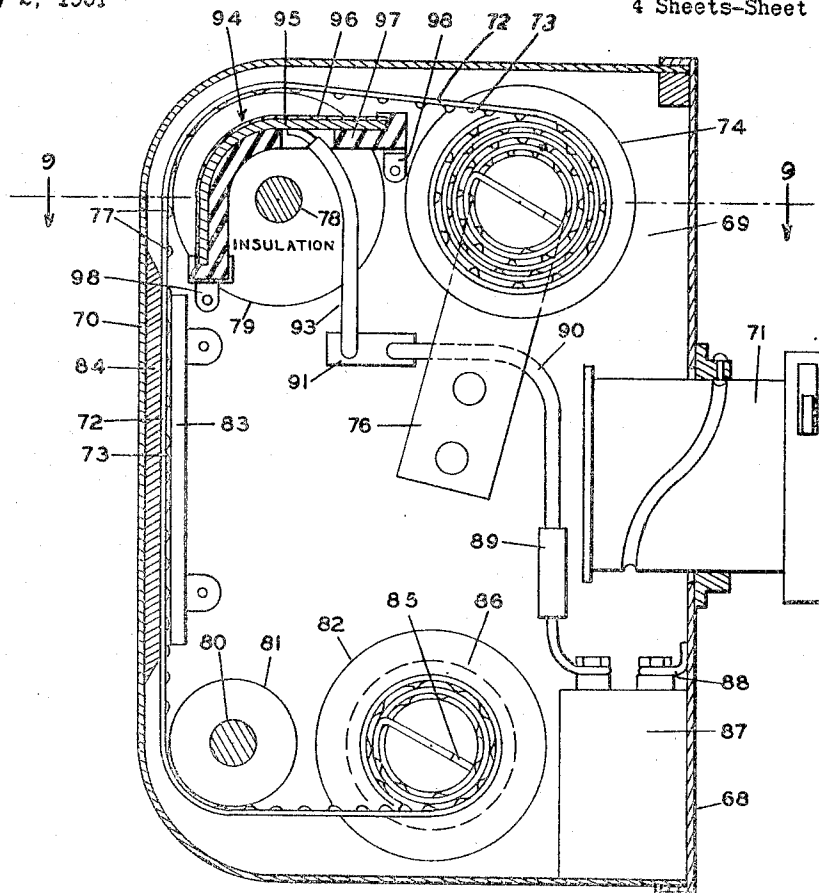
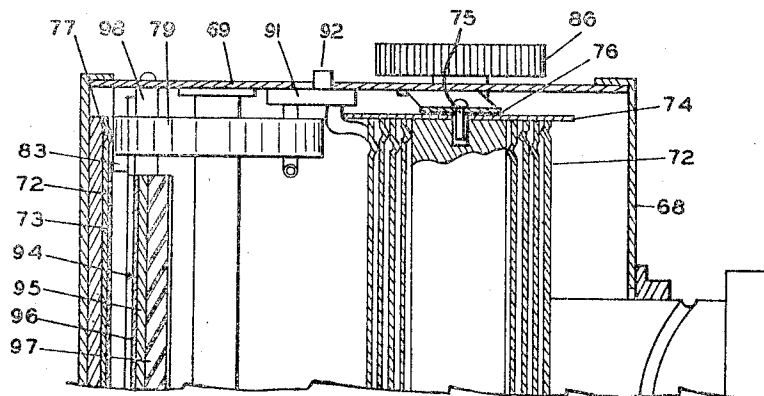


FIG. 9



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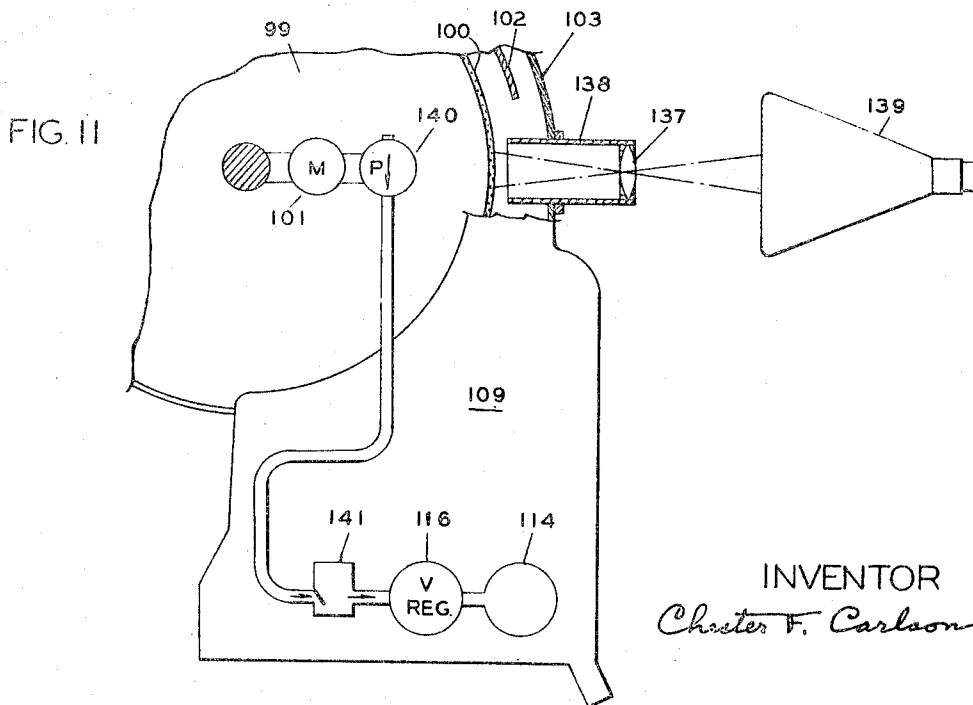
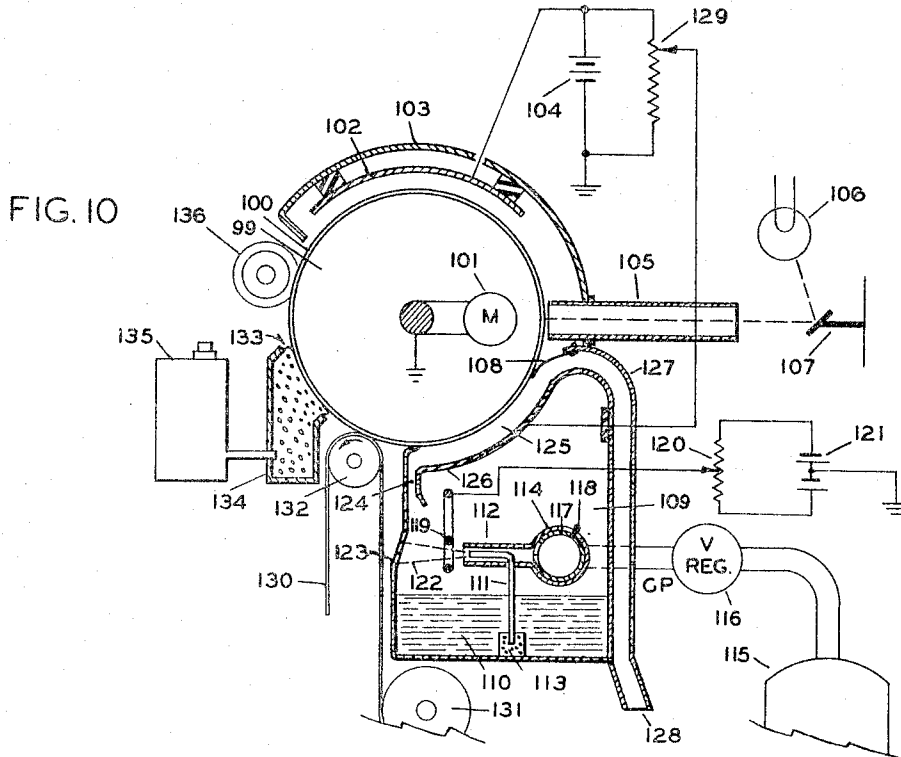
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ELECTROPHOTOGRAPHIC APPARATUS AND METHODS

Chester F. Carlson, Fairport, N. Y.

Application May 2, 1951, Serial No. 224,230

10 Claims. (Cl. 95—1.9)

This invention relates to electrography, to methods and means for charging electrophotographic and electrophotographic plates, and to electrophotographic apparatus embodying such charging means.

A process of electrophotography is described and claimed in Carlson Patent 2,297,691 issued October 6, 1942 and certain electrophotographic apparatus is disclosed in Carlson Patent 2,357,809 issued September 12, 1944. Electrophotography utilizes an electrophotographic plate which in one form may consist of a metal plate or foil coated with a photoconductive insulating material such as sulphur, anthracene, an insulating form of selenium or the like. This coating is given a uniform electrostatic charge on its surface, as by frictional rubbing with a cloth or brush, after which the plate may be exposed to a light image. The light discharges the coating in the areas which are struck by light. The remaining electrostatic latent image may then be developed with a finely divided material, such as a powder or a liquid mist, to form a visible image. The image may then be transferred to paper and the plate may be cleaned and used again.

With the frictional charging means a sufficiently uniform charge can be produced on the plate to permit the production of acceptable line images. However, with the refinement of the process of electrophotography and its application to the reproduction of continuous tone images the demands for uniformity of charging and of more accurate predetermination of the potential on the coating have become more exacting.

One advance which has been made in charging devices comprises the substitution of a filament connected to a high voltage source for the frictional charging means. One such arrangement is disclosed in my copending application Serial No. 500,207, filed August 27, 1943, now Patent 2,551,582, granted May 8, 1951 and is described and claimed in my copending application, Serial No. 212,812, filed February 26, 1951, now Patent 2,588,699, granted March 11, 1952 which is a division thereof. This arrangement permits the charging of a plate to a higher potential than can be obtained frictionally and the plate potential can be predetermined approximately, by regulating the charging voltage and controlling the speed at which the plate is passed under the charging source. It is apparent that this means requires regulation of the high voltage source and of the speed of the plate under the source if close control of the plate voltage is to be obtained. While such an arrangement is suitable for stationary equipment, the power supply requirements are difficult to meet in compact portable equipment.

The present invention contemplates a charging means for electrostatic image plates, and methods of charging such plates, in which a radioactive source is provided to generate ions in front of a plate to be charged and an electrical field is imposed to carry the ionic charges to the surface of the plate. The preferred embodiment of the invention comprises a radioactive source supported in front of the plate to be charged and a potential source connected to apply an electric field between the source and the plate. The plate may be held stationary during charging or the plate and source may be moved relative to each other.

While the invention is especially suitable for the charging of electrophotographic plates it may also be used for the charging of other electrographic or electrostatic image plates, such as electrical printing plates comprising conductive plates provided with designs or images of insulat-

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ing lacquer or other insulating material, such as the plates shown in Figures 10 and 11 of Carlson Patent 2,357,809, for example.

The invention provides a ready means for charging plates more accurately than has heretofore been possible to a predetermined voltage and because of the simplicity and light weight of the charging means is readily adapted to portable equipment, such as cameras, recording devices, and the like. The invention therefore contemplates within its scope both portable and stationary cameras, recording meters, data recording devices, radiographic installations and the like, as well as separate plate charging units.

Combined charging units are also contemplated in which two or more different charging means are provided.

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

In the drawings:

Figure 1 is an elevation, partly broken away, showing one embodiment of my invention utilizing a radioactive source;

Figure 2 represents a modified charging unit and illustrates the condition at the start of charging;

Figure 3 is a face view of the underneath of the top plate of Figure 2;

Figure 4 is a view similar to Figure 2, showing the condition at a later stage of charging;

Figure 5 shows a still further modification in which a radioactive source is used in combination with an electrode for applying a field in front of the plate to be charged;

Figure 6 illustrates a modification in which the ion producing source is supplementary to frictional charging means;

Figure 7 shows still another combined charging unit in which the ion producing source is combined with a corona charging means;

Figure 8 is a section through a portable camera incorporating a radioactive charging means;

Figure 9 is a section, partly broken away, on the line 9—9 of Figure 8;

Figure 10 illustrates a graphic recording device embodying an ion charging means;

Figure 11 is a fragmentary view of a data recording device embodying features of the present invention; and

Figure 12 shows a continuous radiographic unit for producing X-ray images of solid objects.

The device shown in Figure 1 is a plate charging unit for use in laboratory or darkroom. It comprises a flat box-like cabinet having a horizontal metal base plate 20 supported on legs 21. An electrophotographic plate 22 is shown laid on the base plate with its photoconductive layer 23 upward, in position for charging. Base plate 20 is somewhat larger than plate 22 and is provided with a rounded notch 24 in its front edge to permit easy manual placing and removal of the electrophotographic plate 22. The side walls 25 of the cabinet and the back wall 26, all of insulating material, rest on plate 20 along its sides and rear edge, respectively, and are secured in place by screws 27 passing upward through legs 21 and plate 20. A top plate 28, preferably of insulating material, rests on top of walls 25 and 26, and the front wall 29, shown partly broken away, extends only half way down the front of the housing leaving an opening below to permit insertion of the plates for charging.

An ion-producing source comprising a metal plate 30 coated on its lower face with a radioactive coating 31 is mounted by screws 32 under top plate 28. The coating 31 is preferably of the same area as the photoconductive coating 23 on the electrophotographic plate to be charged. The preferred coating 31 is an electroplated coating of polonium. If desired the polonium layer may be protected with a film of gold which is sufficiently thin to permit radioactive emission of alpha particles from the polonium into the air. A gold film of 2 microns or less is satisfactory.

A D. C. potential source, such as a battery 33 is connected between base plate 20 and one of mounting screws 32 which is in electrical contact with the plate 30. The potential source has a voltage equal to or slightly greater

than the potential desired on the charged electrophotographic plate.

In operation, in order to charge an electrophotographic plate to a predetermined potential it is only necessary for the operator to place the plate in position face up on base plate 20, allow it to remain there for a few seconds or more and then remove the charged plate. It is then ready for use in making an exposure to a light image or other source of radiation to be recorded.

The following is believed to be an explanation of the process which takes place during charging: Alpha particles emitted by the polonium layer 31 into the air produce both positive and negative gas ions (and electrons) in the space between plates 22 and 30. The positive and negative ions are equal in number. Battery 33 imposes an electrical field between plates 22 and 30. If plate 30 is connected to the positive terminal of the battery the field is such as to drive positive ions toward the plate 22 and negative ions and electrons in the direction of plate 30. While many of the ions and electrons probably recombine to form neutral molecules before reaching either plate there are many positive ions which reach coating 23 and deposit their charge on it. As a positive charge builds up on insulating layer 23 the effective potential of its surface is raised, thereby reducing the electrical field between the plates. Ions continue to deposit until a state of equilibrium is reached as the potential of the charged photoconductive layer 23 becomes substantially equal to, or slightly less than the potential of plate 30. In other words the plate has then acquired a potential nearly equal to that of battery 33.

While any radioactive source which emits ionizing particles may be used for layer 31 it is, of course, undesirable to adopt sources which involve hazards in their use. Polonium is the most suitable and readily available source. It emits only alpha particles which are harmless even if they strike the skin. There is no radioactive hazard connected with its normal use. Radiothorium would also be suitable.

The alpha particles emitted by polonium have a range of about 1.6 inches. While I have charged electrophotographic plates at spacings of 2 inches and greater from the polonium layer the most effective charging takes place when the plate to be charged is supported within the range of the alpha particles so that the ion cloud is created close to the plate surface. The preferred spacing from the source is less than 1.6 inch and greater than 0.25 inch with 0.5 inch as about the most effective distance. At this spacing the photoconductive layer is in the zone of greatest ion generation. Closer spacings reduce the air volume available for ionization. Greater spacings permit recombination of a large proportion of the ions in the gas. The potential gradient produced by the imposed battery voltage is also reduced as the spacing is increased.

The results indicate that those alpha particles which strike coating 23 do not harm it, nor do they appear to cause any substantial discharge of the electrical charge being built up on the plate by the deposition of gas ions.

The rate of charging will depend on the concentration of polonium in coating 31. A concentration of 1 milligram per square inch will permit charging a plate to several hundred volts potential in a few seconds. I have found by electrometer measurements that the equilibrium potential reached by the charge on coating 23 is usually slightly less than the potential of the battery used. Thus, in some cases it may be necessary to use a battery voltage equal to 110% or more of the voltage desired on the coating. A charging device can readily be calibrated by making electrometer measurements of the plate potential obtained with various battery voltages. A given battery potential will give accurately reproducible plate potentials in successive chargings during use. The electrophotographic plate may be left in the charging device for an indefinite period once the equilibrium potential has been reached, even for several hours or days. The charge on the plate is maintained constant by the device so that the plate is ready for use at any instant required.

The polarity of the charge created on the coating 23 may be made either positive or negative by reversing the connections of battery 33.

Polonium has a half-life of about 140 days, so that the effectiveness of the source gradually declines. When the charging rate becomes too low for practical use the element 30, 31 may be replaced.

The current drain on battery 33 is very small and miniature B-batteries may be used where compactness is desirable. If the unit is to be out of service for an extended period it is desirable to disconnect a miniature battery to avoid the small steady current drain.

Figures 2 and 3 illustrate a charging unit in which the radioactive source covers a smaller area than the coating to be charged. Instead of plate 30, a pair of narrow metal strips 34 are secured to top plate 28. These are electro-plated with a layer 35 of polonium, over which is plated a very thin coating of gold 36.

I have used such a charging unit to produce a substantially uniform charge over the entire area of an electrophotographic plate. It is believed that charging takes place progressively as illustrated by the broken lines in Figures 2 and 4. The situation at the start of charging is shown in Figure 2. The outer limit of the range of the alpha particles is indicated by curved boundary lines 37. Within this volume both positive and negative ions are produced in equal numbers by bombardment of the gas molecules by the alpha particles. The electrical field created by the battery potential is most concentrated in the short perpendicular paths between bars 34 and plate 22 as indicated by lines 38. With the negative pole of battery 33 connected to strips 34 the field is such as to drive negative charges along lines 38 to coating 23 where they build up a negative charge 39. (Figure 4) on the coating directly underneath strips 34. As the negative potential of these areas approaches that of the bars 34 the electrical field gradually shifts, as shown in Figure 4, so that lines 38 are now spread out into a new configuration 38a extending to the still uncharged areas of coating 23. The negative ions are now driven to these new areas along lines 38a even though part of these areas may be outside the range of the alpha particles which produce the charges. The coating 23 is thus progressively charged until its entire area is charged. The radioactive elements 34 can obviously have other forms, such as spaced spots on a metal electrode plate.

Figure 5 illustrates another charging arrangement in which the electric field above coating 23 is provided by an electrode 40 independent of the radioactive source. The plate 40 is connected to the battery and metal bars 41 carrying polonium coatings 42 are suspended along the sides of the air space between plates 22 and 40 so that alpha particles are emitted into the space. It is not necessary that bars 41 be connected into the circuit, although they may be electrically connected to plate 40, if desired. The bars may be of various shapes and may even comprise an array of polonium plated wires or filaments suspended between the plates 22 and 40.

Figures 6 and 7 illustrate composite charging arrangements in which a radioactive charging unit is combined with another form of charging unit. This has the advantage that the "rough charging" may be done rapidly with the latter unit to be followed by a "finish charging" or smoothing operation with the radioactive unit.

Figure 6 illustrates the invention applied to the electrophotographic apparatus shown in my Patent 2,357,809. Electrophotographic plate 53 is carried around drum 54 in a clockwise direction. The plate first passes under rotating brush 55 which performs the combined function of brushing off residual electroscopic developing powder from a previous image and of frictionally applying a new electrostatic charge to the layer. The removed powder is drawn off by an air stream through suction passage 56 leading to a suction system. The polarity of charge applied to the photoconductive coating of plate 53 will depend upon the triboelectric relationship between the material of the brush and that of the photoconductive coating. Anthracene-coated plates normally become charged negatively by most natural brush fibres. The charge imposed on the plate by the brush, while fairly uniform, may exhibit some variation in potential from point to point, and may be either higher or lower in potential than is desirable for optimum exposure conditions.

Adjustment and smoothing of the plate potential is effected subsequent to the brush charging by passing the plate under electrode 57 coated with a radioactive layer 58 and held at a predetermined potential by battery 59. If a plate area is below equilibrium potential, charge will be added, while if an area is overcharged the opposite polarity of charge will be attracted from the ion cloud to reduce the potential of the layer to the required value.

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This will be readily apparent if it is considered what takes place if the plate is charged to an excessive negative potential. The negative potential of electrode 57 will then be lower than that of the plate and the resultant electrical field is such as to drive positive charges to the plate 53. The combined charging unit has the advantage of effecting rapid charging of the plate to a predetermined potential with the minimum of expensive radioactive material. Since the rough charging is done by other means a weak polonium or other radioactive source can effect the small adjustments of plate potential at a rapid rate.

In the composite charging unit of Figure 7 the charging brush is replaced by a grid 60 of very fine conductive filaments strung between insulating end blocks 60a and high voltage generator 47 to produce an electric corona discharge from the grid 60 to plate 53. Either positive or negative corona can be produced depending on the polarity of the filament. Radioactive-coated electrode 57 effects an adjustment of the plate potential to a predetermined value as before. In this case electrode 57 is held at a predetermined potential by voltage regulator circuit 61 comprising a potentiometer 62 by which the potential desired on the electrode 57 may be selected by varying the setting of a sliding contact. The potentiometer is fed by a transformer 63 through rectifier 64, the fluctuations in voltage being smoothed by condenser 65 and resistance 66. A gas discharge tube 67 of the type known as a voltage regulator tube, whose characteristic is to conduct current when the applied voltage exceeds a critical value, is bridged across the terminals of potentiometer 62 to hold the voltage constant.

Figures 8 and 9 are sectional views of a portable camera embodying radioactive charging means for charging an electrophotographic plate preparatory to exposure. The camera housing comprises a front plate 68, side walls 69, and a removable cover 70 which extends around the top, rear and bottom of the camera. A conventional lens and shutter in focusing tube 71 are mounted in the center of front wall 68. The electrophotographic plate comprises a long "film" or strip of metal foil, such as aluminum foil, or metal-coated plastic 72, coated on the inside face with a thin layer of photoconductive insulating material 73 such as anthracene, sulphur or selenium, and is reeled off a supply reel 74 comprising a spool held on pintles 75 in leaf springs 76 riveted to the side walls 69 of the camera.

In order to prevent contact between the surface of coating 73 and the back of strip 72 when adjacent turns are brought against one another on the reel the uncoated marginal edges of strip 72 are provided with a series of small spaced projections or dimples 77 which project out from the face of the strip by a distance exceeding the thickness of coating 73. These projections may be stamped up from the material of strip 72 itself. This leaves recesses in the back of the strip, and in order to prevent the projections from seating in the recesses of an adjacent turn on the reel the projections are stamped in a non-recurring pattern. An alternative method of forming projections comprises applying droplets of a viscous plastic cement to the marginal areas and allowing them to harden. A continuous raised margin can also be applied as a coating of heavy-bodied enamel or lacquer, or strips of paper may be cemented along the marginal edges.

A rotary shaft 78 is mounted to the rear of reel 74 and parallel to it and carries a pair of wide flanges 79 near its ends. A second rotary shaft 80 provided with flanges 81 is mounted between side walls 69 in the lower rear part of the camera and a take-up reel 82, similar to reel 74, is mounted forward of shaft 80. Reel 82 is provided with a keyway in its left end which fits onto a key portion on the inner end of the shaft of manual film advance knob 86 journaled on left side wall 69, as is well known in the camera art. The other end of reel 82 is clipped in the end of a spring similar to 76. A pair of vertical guide bars 83 are secured to side walls 69 near the rear of the camera, the flanges 79 and 81 together with bars 83 providing vertically aligned guides for the marginal edges of strip 72. A flat plate 84 is mounted on the inside of the rear wall of cover 70 and spaced behind bars 83 by a distance slightly greater than the overall thickness of strip 72 and its projections.

The camera is loaded by removing cover 70, clipping a full supply reel 74 into position and leading the free end of strip 72 over flanges 79, along bars 83, under flanges 81 and inserting the leading edge into slot 85 in

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the body of empty take-up reel 82. The film-advance knob 86 may then be turned to advance the strip 72 as desired. When cover 70 is replaced, plate 84 is brought against the back of strip 72 to hold it in the exposure plane with the marginal projections 77 touching flanges 83.

The built-in charging means is supplied by one or more small B-batteries 87 mounted inside the camera below the lens tube. Batteries providing a total open-circuit voltage of 100 to 150 volts are sufficient for most requirements. One terminal of the battery assembly is grounded to the camera case by a spring contact 88. The other terminal, which is of the polarity desired on the electrophotographic plate to be charged, is connected through a small protective resistance 89 to insulated conductor 90 leading to a small switch 91 mounted on side wall 69 and controlled by a manual slide-button 92 on the outside of the wall. A conductor 93 extends from the switch to the radioactive charging element 94 which comprises a curved metal plate 95 coated with a radioactive coating 96 which is in spaced parallel relation to the face of coating 73 on strip 72 where the strip rests marginally against flanges 79 and also for short distances along the strip where it extends away from the flanges 79 toward reel 74 and toward bars 83. Plate 95 is backed up by an insulating support 97 secured by mounting brackets 98 to the side walls 69. The length of strip 72 exposed to the charging element at one time is preferably equal to or greater than the length of the area to be exposed to light from the lens in taking a picture.

When the camera is not in use switch 91 may be kept open to prevent the small but steady drain on the battery resulting from conduction in the ion cloud. The field produced when the battery is connected will carry some ions to any adjacent grounded metal surfaces. Flanges 79 are preferably made of insulating material and are spaced as close to the borders of coating 73 as is practicable in order to cover the bare metal margins of strip 72.

In use, the switch 91 is closed and after the few seconds required to charge the coating 73 to equilibrium potential the strip is advanced by knob 86 to bring the charged area into exposure position, after which an exposure can be made by operating the camera shutter. While an exposure is being made the next frame area is being charged so that successive exposures can be made rapidly if desired. If there is a substantial period between exposures the coating is maintained charged and ready for use by the charging means. The exposed strip, carrying electrostatic latent images resulting from the series of exposures, is wound up on reel 82 where it may be left for several hours, if necessary, before it is removed in a darkroom and developed with finely-divided material (powder or liquid mist) as described in my Patent 2,297,691 or application S. N. 500,207, now Patent 2,551,582 for example.

Figure 10 shows a portable graphic recording device embodying a continuous charging arrangement. A metal drum 99 provided with a coating 100 of photo-conductive insulating material is rotated clockwise by motor 101 which may be a battery-powered electric motor, a spring motor or a hand-crank. The coating passes under radioactive-coated plate 102 in housing 103, which plate is biased to the desired charging potential by battery 104. This imposes a uniform charge on the coating. It then passes a light tube 105 through which is projected a beam of light from lamp 106 by mirror 107 connected to the armature of an instrument whose reading is to be recorded. The charge on the coating 100 is discharged along a path where the light beam strikes the coating and this path is varied laterally across the drum surface as determined by the swing of the mirror. The exposed coating then passes under sliding flap 108 of cellulose acetate, or other insulating sheet material which slides lightly on the surface of the coating and does not materially interfere with the charge distribution.

The charge on the coating is developed by the liquid mist apparatus mounted adjacent to the lower right hand quadrant of the drum. This comprises a mist generating chamber 109 the bottom of which comprises a reservoir for developing liquid 110 which consists of a solvent and a dissolved dye. Water colored with a water-soluble dye, such as from one-half to one percent of nigrosine may be used. Also a colloidal suspension of a fine pigment, such as of the so-called soluble Prussian blue, may be used. Alcohol or ester solutions of spirit soluble dyes, such as aniline blue may also be used. Isopropyl alcohol, butyl

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alcohol, amyl acetate, or a still higher boiling solvent is usually preferable to the more volatile solvents.

The liquid is drawn up through a small tube 111 which extends to an outlet which is surrounded by a larger gas jet tube 112 of an atomizer. A porous filter 113 surrounds the inlet end of tube 111 to remove any sediment particles. Gas jet tube 112 is connected to a larger gas supply tube 114 which is supplied with gas at substantially constant pressure by gas cylinder 115 through pressure control valve 116. The size of the opening leading from tube 114 to jet tube 112 is preset by adjusting the position of apertured sleeve 117 which can be rotated inside tube 114 by lever 118. A single atomizer is sufficient for developing a graph on a narrow drum but where wider drums are used two or more atomizers may be connected at spaced intervals along tube 114 to provide an array of parallel jets.

For purposes of charging the liquid droplets as they leave the atomizer a metal ring 119 is spaced close to the atomizer outlet surrounding the zone where droplets leave the atomizer and is connected to a sliding contact on a potentiometer 120 connected across a battery 121 whose center plate is grounded. Ring 119 can thus be held at any desired positive or negative potential to charge the liquid droplets by induction as they are detached by the air stream from the end of tube 111. A stream 122 of charged liquid mist is produced by the atomizer and projected against side wall 123 of the chamber. The wall is slanted downwardly and outwardly at the place where the horizontal jet strikes it so that undesirable larger drops which may be produced are impinged against the wall and driven downward toward the bottom of the chamber.

The air stream, carrying the fine drops which haven't been separated by impingement, passes upward and out of the chamber through tapered passage 124. Passage 124 leads to one end of the development space 125 which is a narrow gap between the surface of drum 99 and a curved development control electrode 126 extending around the lower right hand quadrant of the drum from passage 124 to the region of flap 108, where it curves away from the drum and turns downward to form one wall of a downwardly extending escape duct 127 leading to an outlet 128 at the bottom of the device. Electrode 126 is insulated from the frame but is connected to the sliding contact of a potentiometer 129 bridged across battery 104, whereby electrode 126 can be held at any desired potential up to the maximum potential of the battery.

If it is desired to deposit droplets on the line or curve discharged by the light beam, potentiometer 129 is set to hold electrode 126 at approximately the same potential as is placed on the coating 100 by electrode 102 during charging. Thus, if battery 104 charges coating 100 to a positive potential of ninety volts, the potentiometer 129 will be set to hold electrode 126 at a positive potential of approximately ninety volts. Electrode ring 119 is set at a negative potential with respect to tube 111 to induce a positive charge on the liquid droplets issuing from the atomizer. It will be apparent that as the air stream carries the positively charged droplets through the development space 125 there will be no electrostatic field tending to deposit them on the unexposed areas of coating 100, other than the small space charge created by the charged droplets themselves. However, where the light beam has discharged a path on the plate the field will be in such direction as to drive positively-charged liquid droplets to the surface of coating 100 where they are deposited to form a visible line or curve of liquid dye. The small space charge created by the droplets themselves may, in some cases, produce a slight deposit of liquid on the unexposed areas. This can be prevented by adjusting the potential of electrode 126 to be slightly lower than that on coating 100 so that the drops will be driven away from the charged areas of the coating and toward electrode 126. This increases the amount of liquid which deposits on electrode 126. This liquid drains back into chamber 109.

If it is desired to reverse the development process to deposit liquid on the unexposed, or background, areas and leave the curve drawn by the light beam as a white line it is only necessary to move the contact of potentiometer 120 so as to induce negative charges on the drops and to set the contact on potentiometer 129 nearer to ground potential.

As the coating 100 passes the developing space 125 it

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picks up liquid drops on the curve, or background, depending upon the setting of the potentiometers, and carries the liquid layer to a transfer position where a strip of paper 130, fed from a supply roll 131, is rolled against the liquid deposit by rubber roller 132. The liquid image is thus transferred to the paper. The liquid solvent used for the dye solution 110 is sufficiently non-volatile to remain as a liquid layer or coating 100 until it is transferred to paper 130, after which it gradually evaporates to leave a dye image or graph on the paper strip. The choice of solvent for a particular recording will be governed in part by the ambient temperature, less volatile liquids being used in warmer locations, and with slower recording speeds. Paper 130 is slightly porous so as to absorb the dye solution at the point of contact. In some cases a dye accepting coating may be provided on the paper, such as a thin gelative layer which will absorb and fix the dye in the configuration in which it is picked up from layer 100.

The paper 130 removes substantially all the liquid dye from the photoconductive layer 100. Since the drum 99 is cycled repeatedly in the machine it is desirable to remove any remaining traces of dye from layer 100 before the layer is again charged and exposed. A porous wiper 133 of natural or manufactured sponge, felt or the like is supported in a cup 134 adjacent the drum to wipe the surface of coating 100 as it leaves the transfer position. The wiper is preferably kept moist with a dye solvent, such as water or an alcohol, which is fed into cup 134 from reservoir 135. A more volatile solvent may in some cases be used for cleaning than is used for developing. A roller 136 having a porous covering is mounted in a position to roll against the coating 100 after solvent cleaning to absorb any liquid not yet evaporated. The covering of roller 136 may be of felt, blotting paper, or the like. As a given area of the coating 100 passes out from under roller 136 it travels a short distance in open air to evaporate any remaining solvent film and then enters housing 103 where it is recharged by electrode 102 and the cycle is repeated.

Figure 11 shows a modification to the apparatus of Figure 10 in which light tube 105 is replaced by a lens 137 mounted in a lens tube 138 to focus an image on coating 100, such as the image of a moving spot, or of lines of characters or insignia produced on the fluorescent face of a cathode ray tube 139. Thus rows of numbers or letters can be rapidly flashed in sequence on the face of the tube and recorded in successive rows on coating 100. Figure 11 also shows a modification in the gas supply for mist generating chamber 109. Motor 101 in this case is an electric motor which drives drum 99 through a gear train and also operates a small air pump 140, such as a piston pump, which maintains pressure in air accumulator tank 141 from which it is fed through constant pressure valve 116 to tube 114 which supplies the atomizer.

Figure 12 illustrates an X-ray inspection unit for the continuous inspection of castings, packaged products or other articles 142 carried by a moving conveyor belt 143. An X-ray tube 144 is mounted above a station passed by the belt and an endless band 145 having a conductive base and a coating 153 of insulating material which is rendered conductive by X-rays is arranged to run on spaced drums or pulleys 146 and 147 underneath the belt. Drum 146 is driven, as by belt 148, from the shaft of pulley 149 around which conveyor belt 143 passes so that the top portion of band 145 which passes from drum 147 to drum 146 is advanced parallel to the belt 143 at the same speed as the belt.

A radioactive charging electrode 150 in housing 151 connected to battery 152 through switch 160 charges the insulating surface coating 153 to a predetermined potential as it passes up around drum 147. When the coating passes under the beam of X-rays from tube 144 it is discharged in proportion to the quantity of radiation reaching it through the objects 142. The X-rays are restricted to a substantially perpendicular beam by lead shield 154 and coating 153 travels as close as is practicable to belt 143 to obtain good definition.

As the belt is carried around drum 146 it passes a liquid mist developing chamber 109, similar to that of Figure 10, and the resulting liquid images are transferred to a strip of paper 156 to produce a continuous radiograph of the objects conveyed by the belt 143. The belt then passes a solvent cleaning wiper 158 and a pair of

blotting rollers 159 which remove remaining liquid traces, after which it begins a new cycle.

Coating 153 may be formed of an insulating form of selenium, or of any other insulating material which is conductive under X-rays. Switch 160 is a reversing switch which permits either polarity to be applied to electrode 150 to charge the coating 153 to whichever polarity yields the best results for the type of inspection desired. The polarity and magnitude of the charge on the developing liquid droplets and on the development control electrode can be adjusted as described in connection with Figure 10 to yield either a positive or a negative electroradiograph, and to adjust the density of the image.

The charging means of the present invention permit the charging of plates accurately to predetermined potentials. This is especially advantageous for the production of continuous tone electrophotographs or electroradiographs where the densities of the various parts of the developed images depend upon the potentials.

The invention is adapted to use in compact light weight portable equipment, such as cameras and portable graphic recording devices. Due to the low voltages required such equipment may be used at high altitudes, such as in airplanes, without the difficulties associated with high voltages at reduced atmospheric pressures.

The radioactive charging arrangements can be used to maintain a charge on a plate and hold it ready for instant use at any time without danger of overcharging or damage to the photoconductive coating. The charge applied to the plate can be changed in polarity by reversing the battery or voltage supply connections. The charging unit may also be used for the continuous charging of image plates either alone, or as a potential smoothing device associated with other charging means.

For charging the photoconductive coatings of electrophotographic plates the voltage of the potential source or battery used with the radioactive element is preferably between 80 and 800 volts depending on the potential desired on the electrophotographic plate. Potentials greater than about 800 volts are liable to damage the plates due to electrical breakdown of the photoconductive layer, and charges less than about 80 volts have insufficient attraction for the finely-divided material used to develop the electrostatic images.

An economical and rapid means is provided for graphic recording of meter readings, cathode ray tube images or insignia, and for producing permanent X-ray records.

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

What is claimed is:

1. Electrophotographic apparatus comprising, in combination, a first charging device and a second charging device, plate support and transport means to support an electrophotographic plate and move said plate in a path substantially parallel to its photoconductive surface under said first charging device and subsequently under said second charging device, said first charging device being capable of effecting rapid charging of said plate surface, and said second charging device comprising an alpha particle source and a potential source for creating an electric field from the vicinity of the ionization produced by said alpha source to the photoconductive surface of said plate.

2. Electrophotographic apparatus as claimed in claim 1 in which said first charging device is a frictional charging element in position to engage the photoconductive surface of said plate.

3. Electrophotographic apparatus as claimed in claim 1 in which said first charging device is a corona discharge element held at a corona-generating potential with respect to said plate and said second charging devices is an alpha particle source and a potential source connected to said alpha source.

4. Electrophotographic apparatus as claimed in claim 3 in which said potential source is adjustable in potential.

5. The method of charging an electrophotographic plate which comprises first rubbing the surface of said plate with a frictional charging element and then smoothing and adjusting the charge on said surface by passing said plate under an alpha particle source and producing a po-

tential difference between said alpha source and the conductive backing of said electrophotographic plate.

6. The method of charging an electrophotographic plate having a photoconductive insulating surface layer and a conductive backing, which comprises first passing said plate under a corona discharge electrode held at corona discharge potential with respect to said plate backing, and then passing said plate under an alpha particle source held at a lower potential with respect to said plate backing.

7. An electrophotographic camera, comprising, in combination, a camera housing including a lens and shutter, means for storing and transporting an electrophotographic element having a face of photoconductive insulating material from a storage position to an exposure position in back of said lens, a charging device in said camera comprising a conductive radioactive source facing a position occupied by the face of said electrophotographic element prior to exposure, a battery connected to said camera having a voltage between 80 and 800 volts, conductors connecting the terminals of said battery between said radioactive source and the backing of said electrophotographic element, and an electric switch in series with one of said conductors.

8. An electrophotographic camera as claimed in claim 7, in which said radioactive source has an area facing said electrophotographic element at least equal to the area of said element which is exposed in a single exposure in said camera and the spacing between the surface of said source and said position occupied by the face of said electrophotographic element is between 0.25 and 1.6 inches.

9. An electrophotographic camera, comprising, in combination a camera housing including a lens and shutter, means for storing an electrophotographic element having a face of photoconductive insulating material in a storage position within said camera, manually controlled means for transporting said element from said storage position to an exposure position in back of said lens and through an intermediate position in which said element may be held stationary, a charging device in said camera comprising a conductive radioactive source having a surface facing the position occupied by the face of said electrophotographic element when said element is in said intermediate position, said surface having an area of substantially the same size and shape as an area of said electrophotographic element which can be exposed in a single exposure in said camera, a battery connected to said camera having a voltage between 80 and 800 volts, and conductors from the terminals of said battery to said radioactive source and to the backing of said electrophotographic element.

10. A portable electrophotographic camera comprising, in combination, a camera housing, a lens and shutter for admitting an optical image into said housing, roll mounting elements and film guides for supporting a supply roll of electrophotographic film and for guiding a strip of said film from said supply roll past an exposure position behind said lens, manually controlled means for advancing and stopping said film, an electrically conductive alpha particle emitter mounted in said camera and having a surface at least equal in area to the area of said film which is exposed in taking a single picture with said camera, said emitter surface being supported in spaced relation to the path traveled by the face of said film in approaching said exposure position, a dry battery attached to said camera, conductors forming a circuit connecting the terminals of said battery to said alpha emitter and the backing of said film, respectively, and an electric switch in series with one of said conductors to open and close said circuit.

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