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2,711,481

XERORADIOGRAPHY METHOD AND DEVICE

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FIG. 1

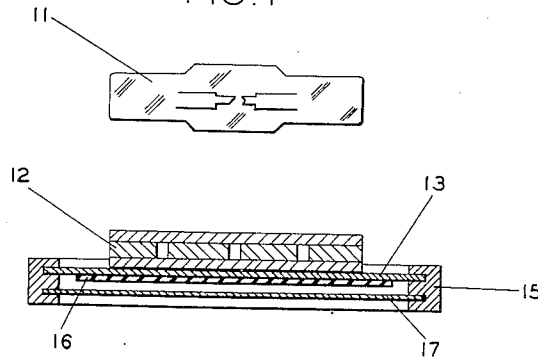


FIG. 2

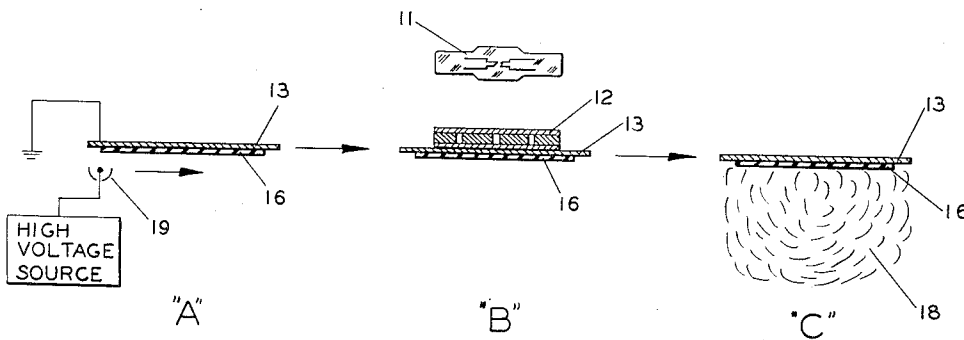
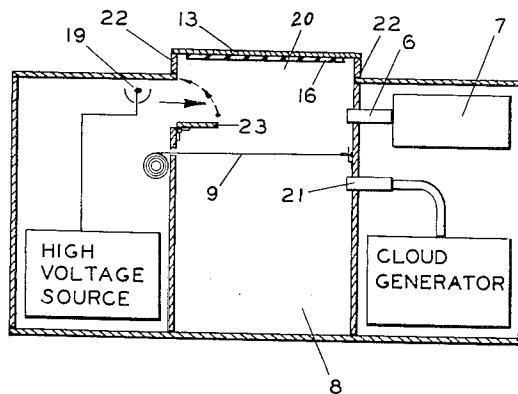


FIG. 3



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XERORADIOGRAPHY METHOD AND DEVICE

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6 Claims. (Cl. 250—65)

This invention deals with the art of electroradiography or xeroradiography and more particularly with apparatus and methods of forming electrostatic images in the art of xeroradiography or electrophotography.

In xeroradiography, as disclosed in Patent 2,666,144, a plate is sensitized by placing on its surface a uniform electrostatic charge, and a latent image composed of electrostatic charges in image formation is created by projecting penetrating radiation through an object and onto the plate surface. The electrostatic latent image may be scanned, or otherwise usefully employed, but most often it is made visible through development of the electrostatic latent image by contacting the latent image on the plate surface with fine powder particles electrostatically charged opposite in sign to the charges making up the image pattern on the plate surface. The visible image may be viewed, photographed or transferred to another surface where it may be permanently affixed or otherwise utilized.

It is an object of this invention to improve the art of electrophotography by providing new means and methods for forming such images on the plate member.

It is an additional object of this invention to improve the art of electrophotography by providing new apparatus for forming such images on the plate member.

It is a further object of this invention to improve the art of xeroradiography by providing new means and methods to obtain an electrostatic latent image of better contrast and of higher resolution than has heretofore been possible.

It is yet another object of this invention to improve the art of xeroradiography by providing means and methods for exposing a plate member to create an electrostatic latent image in less time than has heretofore been possible.

It is another object of this invention to improve the art of xeroradiography by providing apparatus to create an electrostatic latent image of better contrast, higher resolution, and in less time than has heretofore been possible.

It is an additional object of this invention to improve the art of xeroradiography by providing new means and methods of obtaining a developed image of better contrast and of higher resolution, and in less time than has heretofore been possible.

It is an additional object of this invention to improve the art of xeroradiography by providing new apparatus for obtaining a developed image of better contrast and of higher resolution, and in less time than has heretofore been possible.

Other objects and advantages of this invention will be obvious from the following disclosure, when read in conjunction with the accompanying drawings, wherein:

Fig. 1 is a diagrammatic view of one embodiment of the invention;

Fig. 2 schematically indicates a process of xeroradiography carried out according to this invention, and;

Fig. 3 is a diagrammatic cross section of one embodiment of apparatus contemplated by this invention.

Referring more particularly to the drawings, in Fig. 1 penetrating radiation from a source 11 is projected through an object 12 which is to be examined and which rests on and is supported by backing member 13 of a plate in a plate holder or cassette generally designated

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as 15. Backing member 13 is coated with a layer 16 which is an electrical insulator in the absence of penetrating radiation but which becomes conductive in those areas where radiation strikes and is absorbed. A dark slide 17 may be inserted and removed through a slit and along grooves provided in cassette 15.

In Fig. 2 three stages, A, B, and C of the process of xeroradiography contemplated by this invention, are shown. Stage A represents the charging or sensitizing step in the process; stage B, the exposure step; and stage C represents the development step. At step or stage A, the plate member comprising layer 16 overlying backing member 13 is made sensitive by placing a uniform electrostatic charge on layer 16. In this figure, charging is accomplished by the action of corona discharge electrode 19 which supplies a uniform electrostatic charge to the surface of layer 16 while backing member 13 is held at ground potential. Corona discharge electrode 19 is made up of one or a number of fine strands of wire to which a corona emitting voltage is supplied from a high voltage source, and the electrode generally includes a control electrode to limit, or make more uniform, the potential placed on the plate. Other possible ways of applying a uniform electrostatic charge to the surface of layer 16 include, but are in no way limited to, frictional charging or the rubbing of a material selected because of its position in the triboelectric series in relation to the position of the material making up layer 16 against the surface of layer 16, filament emission of electrons which are carried to layer 16 through the action of grounded backing member 13, techniques of air ionization other than corona discharge such as ionizing air through the use of a radioactive material, inducing a charge to the surface combinations of these, and the like. Although the sensitization of the plate is accomplished in this figure and also in Fig. 3 using corona electrode 19 and although corona charging is the preferred means for sensitizing the plate, it is to be understood that other charging methods known to those in the art, as for example those mentioned above, are intended to be encompassed within the scope of this invention.

Once the plate member has been sensitized it is ready for the exposure step which is shown at stage B and in greater detail in Fig. 1. Penetrating radiation from a source 11 is projected to penetrate an object 12 resting on backing member 13 on which is coated layer 16. The exposure step creates on the surface of layer 16 an electrostatic latent image of the radiograph of the object being examined.

The plate member is then ready for the development step shown at stage C where the plate member composed of backing member 13 and layer 16 is exposed to finely divided charged material such as cloud 18 of powder particles. The particles may be charged by passing them through a corona discharge area surrounding corona emitting needles or wires or by turbulently flowing the powder particles in air through a tube or the like composed of material properly positioned in the triboelectric series in relation to the material of which the particles are composed or through the use of other techniques known to those in the art. The electrostatically charged particles deposit on the surface of layer 16 in image configuration due to the action of electrostatic forces of the electrostatic latent image on surface 16 acting on the charges on the particles of cloud 18. Although the preferred form of development is powder cloud development as is shown in Fig. 2, other known means of development are intended to be encompassed within the scope of this invention, as for example, dusting the surface carrying the electrostatic latent image as is disclosed in Patent 2,297,691, cascading a two-component developer across the surface of the plate member as is disclosed in Patent

2,618,552, liquid development and other techniques of development known to those in the art, which effectively produce a visible image.

In Fig. 3 an embodiment of new xeroradiographic apparatus adapted to fully utilize the new methods of this invention as discussed with reference to Figs. 1 and 2 above, is shown. A plate composed of layer 16 overlying backing member 13 is placed on supports 22. The plate is sensitized or charged by passing across the surface of layer 16 corona discharge electrode 19 preferably comprising one or several fine conductive strands supplied with a corona-generating voltage. Door 23 in a side of chamber or compartment 20 opens to allow corona discharge electrode 19 to enter chamber 20. Electrode 19 is driven by conventional drive means while supported and positioned by guide means and when operated will pass in front of and across the surface of plate layer 16 to place thereon a uniform electrostatic charge while backing member 13 is at ground potential. A slide or shade 9 is positioned within one side of compartment 20 and formed to completely enclose cloud storing area 8 and separate storing area 8 from chamber 20 when conventional means are operated for pulling the shade across the bottom of compartment 20. In operation, as will be explained more fully below, the shade or slide 9 may be released to allow it to rewind upon itself due to a spring controlled recoil action creating one open area composed of powder cloud storing area 8 and compartment 20. As is shown in Fig. 3 shade 9 is in position effectively separating cloud storing area 8 and compartment 20. A vacuum cleaner 7 is positioned to allow vacuum cleaner nozzle 6 to extend through a side in compartment 20. Cloud spray nozzle 21 extends through a side of cloud storing area 8 and is supplied from a cloud generator with powder particles mixed in pressurized air. Nozzle 21 has an internal opening which acts on the particles supplied in pressurized air to create a turbulent flow of particles through it. Nozzle 21 should be formed of a proper material chosen from the triboelectric series in relation to the material the powder particles are composed of to impart the proper electric charge to the powder particles flowing through its internal opening. On passage from nozzle 21 into cloud storing area 8 a powder cloud of charged particles is created. This cloud may be used for development purposes when desired.

The apparatus shown in Fig. 3 is capable of carrying out all the steps of the xeroradiographic process contemplated in this invention. An object to be radiographed may be placed on backing member 13 which will act as a support for the object while shade 9 is in a closed position as shown and door 23 is in a closed position (shown in an open position). On operating the equipment, door 23 opens to the position as shown and corona electrode 19 moves across the surface of layer 16 and supplying charges to the plate. At the end of the charging pass door 23 closes. An exposure is then made by causing penetrating radiation to be directed to and through the object resting on backing member 13. The source of X-ray energy may in fact be wired into the circuit of the device shown in Fig. 3 to start automatically following the charging of the plate member. Preferably, during exposure and while shade 9 remains in its closed position a cloud of developer particles in air is supplied to cloud storing area 8 providing a pregenerated powder cloud for development purposes to be used following exposure. This pregenerated powder cloud is supplied to the plate following exposure by the release of shade 9 making storing areas 8 and compartment 20 one enclosure and allowing powder cloud which is already generated and which is being continuously generated during development to flow upward into the area of influence of the electrostatic latent image on the surface of layer 16. After the proper development time has elapsed the shade 9 moves back to its closed position and vacuum cleaner 7 operates to

remove the remaining cloud of particles in air from compartment 20. An air intake valve may also be opened to prevent the creation of a negative pressure within chamber 20. At this point the plate is ready for viewing and the object resting on conductive member 13 is removed to give access to the plate. This cycle of operation which has just been described may then be repeated.

The plate used in connection with this invention may be a conventional plate used in the art of xeroradiography and includes plates generally used in xerographic apparatus. Backing member 12 may be any conductive material, a preferred plate however, having a backing member composed of aluminum or aluminum having a radiation absorbent coating thereon such as a coating of lead. Brass has also been found to work very well with this invention in the higher energy levels and is believed to add substantially to significant values in results. However, the use of brass at lower energy levels increases exposure time due to the high absorbent effect of the brass layer. Other metals or conductors operate very well in this invention when used as backing members in properly formed xeroradiographic plates. Layer 16 should be composed of a material which becomes conductive when exposed to penetrating radiation and which in the absence of penetrating radiation is a good insulator. Such a material will be referred to in this application as "normally insulating," and includes materials which generally will have a resistivity in the order of greater than 10^{12} ohms cm. in the absence of radiation and a resistivity in the presence of penetrating radiation of about 10^3 or 10^4 ohms cm. lower than in the absence of such radiation. Many materials may be employed in accordance with this invention such as amorphous or vitreous selenium, sulphur, anthracene, certain materials of the class generally known as phosphors, and the like. It is to be understood, of course, that the numerous materials listed are only illustrative of the many that may be employed, and it is intended to encompass within the scope of this invention those materials having the insulating and conductive characteristics described above.

As indicated previously, the plate is sensitized by placing uniformly on layer 16 an electrostatic charge. Sensitization may be accomplished when using a plate which is also sensitive to light by the removal of dark slide 17 and by exposure of layer 16 in the dark to a corona discharge electrode or the like as is well known in the art of xerography. In many instances dark slide 17 and the electrostatic charging in darkness are necessary in that some plates are sensitive after and during charging to both penetrating radiation and normal light. It is noted, however, that plates may be sensitive when charged to penetrating radiation and not to light, and when such plates are being used the precautions taken against exposure to light, that is the dark slide and the charging of layer 16 in darkness, may be dispensed with.

In carrying out the steps of this invention the plate is sensitized and placed in an exposure position as shown in Fig. 1 so that radiation having passed through an object will present a pattern of radiation first to the conductive backing member 13 and then to the sensitive charged layer 16.

Although it is not intended in any way to limit this invention, the following is suggested as one possible explanation of what occurs to cause better image resolution, speed, and improved radiographs when a plate is exposed so that radiation first penetrates the conductive backing member 13 and then the sensitive charged layer 16 rather than penetrating layer 16 first after the object. Conductive backing member 13 will absorb the secondary and tertiary X-rays created within the object being examined. Some of these locally generated X-rays move at relatively large angles with respect to the primary beam. The secondary and tertiary X-rays are relatively lower radiation than the primary beam and normally insulating materials may well be more sensitive to such energy

levels than they are to higher energy radiation, and their absorption by conductive backing member 13 improves definition and increases image contrast of the resultant image created on the normally insulating layer. Conductive member 13 also acts as a filter to remove or filter out low energy radiation. As the energy of the source increases, penetrating power of the radiation increases and lower energy radiation will more easily be absorbed and removed than higher energy radiation. This filter effect will be greatest on the lowest energy radiation which will include scattered radiation traveling at wide angles and the removal of such scattered radiation helps to improve image resolution.

Conductive backing member 13 also absorbs direct radiation at the energy level being used and creates secondary X-rays at lower energy levels which are more easily absorbed and detected by sensitive layer 16. This decreases the time necessary for exposure. Since layer 16 is formed on conductive member 13 as a single unit, the secondaries travel an absolute minimum distance and definition is not decreased seriously even though some secondaries may move at large angles relative to the primaries. In addition, those secondaries which are formed within backing member 13 at a point removed from the surface carrying layer 16 traveling at very divergent angles are likely to be reabsorbed within conductive member 13 before reaching sensitive layer 16. Since secondaries are created in proportion to the number of primaries reaching a particular area of conductive member 13, those secondaries which react on sensitive layer 16 which are created in member 13 cause a true representation of the relative absorption of the primaries in the object being examined.

Another beneficial effect of projecting energy first through backing member 13 is that member 13 on being struck by penetrating radiation will emit photoelectrons or beta particles. Such electrons or particles are absorbed by sensitive layer 16 making the particular area absorbing the electrons conductive thereby providing current paths resulting in neutralization of areas of charge on the surface of layer 16. This phenomenon of discharge may also be explained using an electron hole theory. The photoelectrons in penetrating layer 16 lose energy by creating electron hole pairs and these electron hole pairs migrate in a direction controlled by the electrostatic fields of force created between the conductive backing member 13 and the electrostatic charges on the surface of layer 16 resulting in neutralization of areas of charge on the surface of layer 16. Electrons, like secondary X-rays, are emitted in proportion to the intensity of penetrating radiation striking conductive member 13, resulting in discharge or neutralization of areas on layer 16 in amount and in position relative to the absorption within the object being examined thereby producing in electrostatic charge pattern a representation of the object being examined. The emission by conductive backing member 13 of photoelectrons or beta particles further tends to decrease exposure time. Definition on the other hand is not seriously affected due to the structural formation of the plate wherein sensitive layer 16 is formed in union with conductive member 13.

Another beneficial effect of projecting energy first through backing member 13 is that member 13 on being struck by penetrating radiation will emit Compton or recoil electrons and they (unlike photoelectrons) are emitted preferentially in the forward direction to be absorbed by sensitive layer 16. Recoil electrons, like photoelectrons, are emitted in proportion to the intensity of penetrating radiation striking conductive member 13, causing the electrons to discharge or neutralize layer 16 in amount and in position relative to the absorption within the object being examined thereby producing on sensitive layer 16 a valid picture of the object being examined. The emission by conducting backing member 13 of recoil electrons further tends to decrease

exposure time and definition is not seriously affected due to the structural formation of the plate wherein sensitive layer 16 is formed in union with conductive member 13 and because of the preferential forward direction of emission of the recoil electrons.

In many instances in the field of radiography, it is desirable to place the sensitized surface close to the object being examined. Intimate contact is desirable, in some instances, to minimize scattering and to produce truer radiographs. Exposing an object according to this invention allows for positioning of the object in contact with backing member 13. Intimate contact of the object with the sensitive layer has not been possible in the art of xeroradiography in that layer 16 when sensitized carries a uniform electrostatic charge, and placing an object in intimate contact with layer 16 will detrimentally affect the uniformity of the electrostatic charge on its surface and this will, of course, distort the latent image formed on the plate member.

Placing the object at a slight distance as, for example, resting it on dark slide 17 when intimate contact is desirable and directing radiation through the object to the plate results in an image of poorer quality than is possible with the methods of this invention.

Another reason why positioning an object to be exposed to penetrating radiation on the surface of sensitive layer 16 is not possible is because of the delicateness of layer 16 itself. This layer is formed having a uniform thickness throughout and with a critical maximum degree of tolerance allowing for very slight variations. Characteristics of this layer may be substantially affected and permanently damaged if subjected to what for other articles would be normal handling. Scratching even slightly and placing an object in physical contact with layer 16 would create sufficient damage to prevent further use of the plate member.

A further disadvantage of exposing an object to radiation while in contact with the sensitive layer 16 is that many of the plates used in xeroradiography are sensitive to light. This would require exposure in a dark room if an object could be placed on the plate surface. Also many objects which are X-rayed are conductive and would allow charges on the surface to escape.

Although in carrying out exposure according to this invention the object subjected to radiation for examination purposes is not in direct intimate contact with layer 16, it may be supported by a layer of material, conductive member 13, acting beneficially to produce a higher quality radiograph.

Another advantage to exposure according to this invention is that of using conductive backing member 13 as a support for the object being radiographed. For example, in examining castings, samples are often X-rayed and the castings being examined according to this invention may be placed on backing member 13 of a sensitive xeroradiographic plate and exposed to X-ray radiation. This form of exposure, while a portion of the plate member is used for support purposes, had not been possible heretofore.

It is also pointed out that using this invention allows for new means of sensitizing and developing the plate member. The plate may be positioned and ready for exposure and then sensitized by charging with corona discharge or the like while remaining in position for exposure. It may then be exposed or exposure may take place as is otherwise known in the art. While remaining in place it may then be developed.

The particular device shown in Fig. 3 is able to operate in this way and in addition has many novel attributes. The corona electrode when not in use is housed out of contact with developer particles and is thereby protected against powder contamination. The vacuum system removes developer particles from chamber 20 preventing the escape of dust to the room when a plate is not in position. The combination of shade 9 and the vacuum

system also acts to prevent deposition of particles on the plate prior to exposure or on electrode 19 during charging. The shade allows a cloud of material to be stored until needed for development purposes, and so does away with a time lag for the formation of a dense cloud. The shade and vacuum combination may also function to accurately control development time. The entire process, from charging through to the final image on the plate can be done in less time than had been previously possible thereby improving the art. Equipment which may be used as for example the device shown in Fig. 3 extends those fields where xeroradiography may be made applicable.

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. Xeroradiographic apparatus for the creation of xeroradiograph on the surface of a xeroradiographic plate comprising a normally insulating layer overlying a conductive member, said apparatus comprising a compartment, means to support a xeroradiographic plate, the plate support means disposed to position a plate on said compartment with the normally insulating layer of the plate facing inwardly to said compartment, charging means to sensitize said plate by depositing on the surface of the normally insulating layer a uniform electrostatic charge, a cloud storing area adjoining said compartment, means to separate said compartment and said cloud storing area, means to supply a cloud of developer particles to said compartment for development purposes, and means to keep said compartment free of developer particles at all times other than during development of an image on the plate.

2. Xeroradiographic apparatus for the creation of a xeroradiograph on the surface of a xeroradiographic plate comprising a layer of amorphous selenium overlying a conductive backing member, said apparatus comprising a compartment, means to support a xeroradiographic plate, the plate support means disposed to position the plate on said compartment with the selenium layer of the plate facing inwardly to said compartment, a corona discharge electrode to sensitize said plate by depositing on the surface of said selenium layer a uniform electrostatic charge, drive means to move said corona discharge electrode across said compartment and in front of said plate along guide and support means in said compartment, a source of penetrating radiation positioned and disposed to direct radiation after having passed through an object being examined and then through said conductive backing member of said plate to said selenium layer when a plate is in position in said apparatus, a cloud storing area adjoining said compartment, means to generate a mixture of powder particles in air and feed said mixture to a nozzle positioned and disposed to feed said mixture to said cloud storing area in the form of a cloud of particles in air, said nozzle having an internal opening formed to create a turbulent flow of particles in air fed through it and said nozzle being composed of a material characterized by its position in the triboelectric series relative to the position of the material making up the developer particles to impart an electrostatic charge of desired polarity to said particles turbulently flowing through said nozzle, a shade positioned and disposed to separate said compartment and said cloud storing area before and after the development of an image on a plate positioned on said support means, means to remove said shade separating said compartment and said cloud storing area to present said cloud of developer particles in air to a plate in position on said support means for development purposes, and vacuum cleaning means to remove developer particles from said compartment before and after development of an image on a plate.

3. In the method of forming a radiographic latent image pattern of electrostatic charges on a plate com-

prising a normally insulating material overlying a conductive backing member, the improvement comprising sensitizing the plate by placing a uniform electrostatic charge on the surface of the normally insulating layer and exposing the sensitized plate to penetrating radiation while supporting an object to be radiographed on the reverse side of said backing member, said plate being positioned and disposed to cause said radiation to first penetrate said conductive backing member and then enter said normally insulating electrostatically charged layer.

4. In the method of making a radiograph the steps comprising placing a uniform electrostatic charge on the surface of an amorphous selenium layer overlying a conductive backing member, supporting an object to be radiographed on the reverse side of said backing member, exposing said selenium layer to a source of penetrating radiation while the object to be radiographed is positioned between said source and said backing member thereby forming an electrostatic charge pattern of the radiograph of the object being examined on the surface of said selenium layer, and developing said charge pattern on said selenium surface with electrostatically charged finely divided powder particles.

5. Xeroradiographic apparatus for the creation of a xeroradiograph on the surface of a xeroradiographic plate comprising a normally insulating layer overlying a conductive member, said apparatus comprising a compartment, means to support a xeroradiographic plate, the plate support means disposed to position a plate on said compartment with the normally insulating layer of the plate facing inwardly to said compartment, a corona discharge electrode to sensitize said plate by depositing on the surface of the normally insulating layer a uniform electrostatic charge, drive means to move said corona discharge electrode across said compartment and in front of said plate along guide and support means in said compartment, a cloud storing area adjoining said compartment, means to generate a cloud of powder particles and feed the cloud to a nozzle positioned and disposed to feed to said cloud storing area, the nozzle having an internal opening formed to create turbulent flow of particles fed through it and the nozzle being composed of a material characterized by its position in the triboelectric series relative to the position of the material making up the developer particles to impart an electrostatic charge of a desired polarity to the particles turbulently flowing through the nozzle, a shade positioned and disposed to separate said compartment and said cloud storing area before and after the development of an image on a plate positioned on said support means, means to remove said shade separating said compartment and said cloud storing area to present said cloud of developer particles to a plate in position on said support means for development purposes, and vacuum cleaning means to keep said compartment free of developer particles at all times other than during development of an image on the plate.

6. In the method of forming a radiographic latent image pattern of electrostatic charges on a plate, the steps comprising placing a uniform electrostatic charge on the surface of an amorphous selenium layer overlying a conductive backing member, supporting an object to be radiographed on the reverse side of said backing member, and exposing said selenium layer to a source of penetrating radiation while the object to be radiographed is positioned between said source and said backing member thereby forming an electrostatic charge pattern of the radiograph of the object being examined on the surface of said selenium layer.

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