Jan. 26, 1960 R. C. HERGENROTHER 2,922,842

STORED X-RAY PRESENTATION SYSTEMS

Filed June 8, 1955

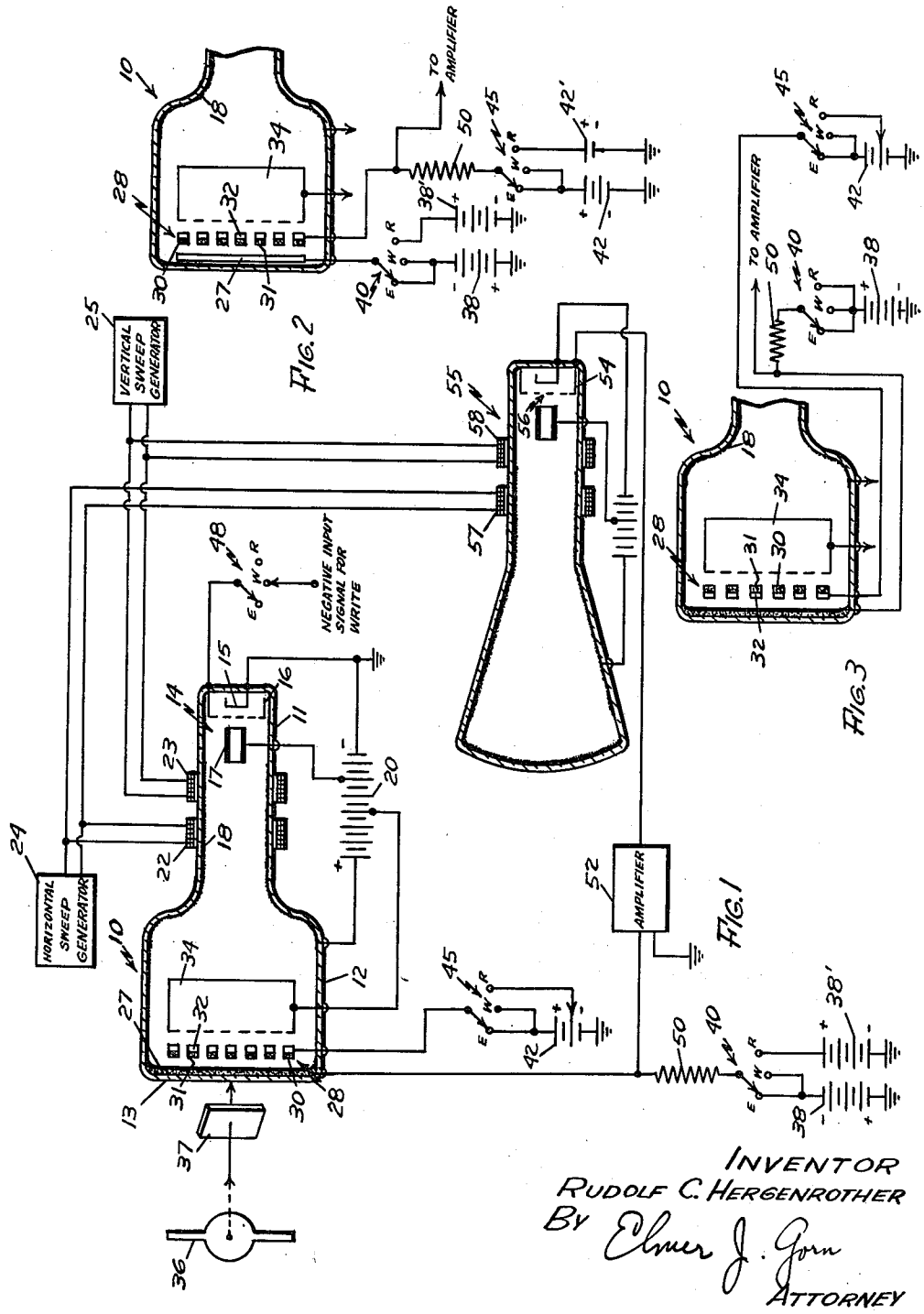


FIG. 2

FIG. 3

FIG. 1

INVENTOR
RUDOLF C. HERGENROTHER
BY Elmer J. Gorn
ATTORNEY

United States Patent Office 2,922,842
Patented Jan. 26, 1960

2,922,842

STORED X-RAY PRESENTATION SYSTEMS

Rudolf C. Hergenrother, West Newton, Mass., assignor to Raytheon Company, a corporation of Delaware

Application June 8, 1955, Serial No. 514,085

10 Claims. (Cl. 178—6.8)

This invention relates to an improved system for examination of objects, either animate or inanimate, by exposure to X-radiation.

A system involving an X-ray image tube has been disclosed in an application by Rudolf C. Hergenrother for U.S. Letters Patent, Serial No. 327,519, filed December 23, 1952, now abandoned, wherein the photoconductive effect is utilized to translate an X-ray shadow image into an electrical charge image which is scanned with an electron beam to produce an electrical output signal. This system, however, requires that the object to be examined must be continuously exposed to X-rays so long as an X-ray image display is required. For this reason, prolonged analyses of a patient under investigation, often necessary, for example, in certain complicated clinical anatomical diagnoses, necessitates an equal prolonged exposure of the patient to X-radiation.

In accordance with this invention, an X-ray image may be written quickly into a storage recording tube having mounted on a supporting element therein a photoconductive storage material whose electrical resistivity is dependent upon the intensity of the X-radiation and the degree of transparency of the object to X-radiation. The X-ray image, once obtained, may be read out for a long period and may be viewed at will by an operator on a synchronously scanned monitor tube. The amount of exposure to X-rays of the patient or object, depending upon whether a system is being used for diagnostic or industrial purposes, is considerably reduced by the system according to the subject invention.

The sensitivity of the system according to the invention may be enhanced, particularly for X-rays of high voltage, if the storage element is a dielectric material containing atoms of relatively high atomic number, such as lead fluoride. The absorption of the X-rays in the dielectric storage material and, consequently, the number of charge carriers produced, is thereby materially increased and the leakage resistance variation of the storage material for a given X-ray intensity is likewise increased. The storage material, in addition to being a dielectric material of high atomic number and high resistivity when not irradiated, must also be characterized by relatively low vapor pressure and a melting point which permits processing in vacuum tubes. For example, when the storage material is deposited on a supporting structure by an evaporation technique, a melting point between about 600 degrees C. and about 1600 degrees C. is required. The halogens and oxides of elements having a high atomic number, high resistivity when not irradiated with X-radiation, and satisfactory melting and boiling points will prove satisfactory for use in the system of the invention.

Further improvement in the sensitivity of the system may be obtained by making the supporting element for the storage material of an electrically-conductive material having a comparatively high atomic number, such as platinum, gold, or lead. Electrons are released from

the supporting element when X-rays of sufficient intensity to penetrate the storage material strike the supporting element. In this way, the photoconductive effect is further increased.

An object of this invention is to provide a system for storing an X-ray image of an object to be examined over a prolonged period.

Still another object of this invention is to provide a system for rapidly deriving a replica of an X-ray image which may be observed at will.

Another object of this invention is to provide means for substantially reducing the hazardous effect upon living tissue resulting from prolonged exposure to X-rays.

Another object of this invention is to provide an X-ray presentation device of high efficiency and low energy requirements.

A further object of this invention is to provide means for producing simultaneous presentations of an X-ray shadow image in a plurality of locations.

Further advantages of this invention will be apparent as the description progresses, references being had to the accompanying drawings wherein:

Fig. 1 is a circuit diagram illustrating an X-ray presentation system according to the invention; and

Figs. 2 and 3 are fragmentary views of modifications of the system shown in Fig. 1.

Referring to Fig. 1, an image-recording storage tube **10** is shown which comprises an envelope, which may be made of glass, having an elongated neck portion **11** and an enlarged portion **12** terminating in an end face **13**. An electron gun **14**, including a cathode **15**, a control grid **16**, a first or focussing anode **17**, and a second anode **18** positioned within the neck **11** of tube **10**. The second anode **18** may, for example, comprise an electrically-conductive coating on the inner surface of the tube, and may extend well into the enlarged portion of the tube. The necessary potentials for the electron gun elements are derived from a unidirectional source of energy, shown by way of example as a battery **20** having taps for connecting to the various electrodes of the electron gun.

Surrounding the neck of tube **10** are horizontal and vertical deflection coils **22** and **23** which are energized by horizontal and vertical sweep generators **24** and **25**, all respectively. Although the deflection system is shown as electromagnetic, an electrostatic deflection system may be used, in which case the deflection coils would be replaced by the usual perpendicular pairs of deflection plates.

A collector-reflector electrode **27**, hereinafter referred to as a target, is mounted on or near the face of tube **10**. Target **27** serves as an electron reflector during the writing operation and as an electron collector during the reading operation, as will be explained more fully later. The target **27** may consist of a conductive coating, such as a thin evaporated aluminum coating on the inner surface of the face **13** of tube **10**, as shown in Figs. 1 and 3. Alternately, the target may consists of a thin electrically-conductive plate mounted within the tube envelope and closely spaced from the face of the tube, as shown in Fig. 2. In either case, the target must be designed so as to satisfactorily transmit X-radiation to storage member **28**, about to be described. The face of tube **10** should be made of a material having a comparatively low X-ray absorption and scattering effect, such as borosilicate lithium glass.

A storage member **28** is positioned adjacent target **27** and generally parallel thereto. Member **28** consists of a storage coating **30** in the form of a layer of X-ray-sensitive photoconductive material, such as cadmium sulphide, deposited, as by evaporation, on an electrically-conductive supporting mesh **32**. The storage coating or layer **30** is

deposited on the side of mesh **32** facing away from the electron gun.

A cylindrical decelerating electrode **34**, having a screen at the end nearest the target, is positioned near the storage member **28** on the electron gun side. Electrode **34** is maintained considerably more negative than the second accelerating electrode **18**, and, together with electrode **18**, forms a decelerating lens, owing to the retardation field between these electrodes, and thus directs the electrons through the decelerating electrode **34** generally perpendicular thereto over a large deflection angle. In one embodiment of the invention, mentioned by way of example only, the second electrode **18** and decelerating electrode **34** were maintained at potentials of 3,000 volts positive, and 300 volts positive, respectively, relative to the cathode **15**.

An X-ray tube **36** is positioned near the enlarged end **12** of storage tube **10** and an object **37** to be examined, shown here by way of example only as a rectangular plate, is disposed between the X-ray tube **36** and the face of storage tube **10**. The object to be examined may, of course, be a portion of the human anatomy, or any other object to be radiographed. An X-ray shadow image is formed in consequence of the passage of X-rays through object **37**.

Before writing on the storage member **28**, an erasing operation is effected; the target potential is made negative relative to the cathode by means of battery **38** connected between the cathode (ground) and target **27**, when switch **40** is in the position designated "E." This negative voltage may, for example, be of the order of —200 volts relative to the cathode. The electrically-conductive mesh **32** of storage member **28** is maintained at some positive potential relative to the cathode by means of battery **42** connected between ground and mesh **32**, when switch **45** is in the position designated "E." In one practical embodiment, the storage mesh voltage was made 40 volts positive relative to the cathode. During the erasure operation the retarding field between the storage member and the target prevents the electron beam from impinging upon the target and causes the scanning beam passing through the apertures in the storage member to be reflected back so as to fall on the surface **31** of the storage coating **30**. The reflected electron beam will strike a particular portion of the storage surface **31**, dependent upon the instantaneous value of the scanning voltages, with a velocity dependent upon the potential of the storage surface. During the erasing operation, the storage member potential, that is, the potential of the storage mesh **32** relative to the cathode, is maintained below the critical voltage, that is, the voltage to which the secondary emission ratio of storage surface **31** is unity, by means of the aforesaid battery **42**. When the storage surface potential is less than this critical potential, the storage surface **31** will charge negatively until it reaches equilibrium at the cathode potential. The entire storage surface **31** of photoconductive layer **30** scanned by the electron beam is thereby uniformly charged to the cathode potential. Switch **48** in the grid circuit of storage tube **10**, to be described later, is also in the position designated as "E" while the storage surface is being erased negatively.

It is possible to erase in two separate steps, that is, to first erase positively by biasing the conductive mesh **32** above the critical potential and then to bias the conductive mesh negatively in the matter already described. This dual-step erasing operation sometimes results in more rapid erasure of the storage coating **30**.

The writing operation can now be described. The movable contacts of switches **40**, **45**, and **48** are now moved to the positions indicated as "W." With switch **48** in the position designated as "W" a negative blanking signal is applied to the control grid **16** of storage tube **10**, and cuts off the electron beam. The potentials applied to the storage screen and target are unaltered during the writing operation, as is evident from examination of Fig. 1. The X-ray tube **36** is then energized so that X-radiation emitted therefrom, after passage through sample **37** and the face **13** of storage tube **10**, impinges upon the surface **31** of the photoconductive storage material **30**. The X-ray image thus obtained is flashed onto the storage member just long enough to vary the charge on the storage surface, in a manner to be described, at various points thereon according to the intensity of the X-ray image at corresponding points.

The photoconductive layer has the property of substantially lowered lowered volumetric resistance when illuminated by X-rays. The projection of the X-ray image on the photoconductive layer results in a variation in conductivity of the layer throughout its volume corresponding to variations in intensity of the X-ray shadow image. Photoconductive layer **30** has an appreciable leakage to mesh or back plate **32** on which it is mounted, and the local discharge of the screen will bring the storage surface **31** to a potential intermediate that of the surface immediately after erasure (that is, cathode potential) and the potential, determined by battery **42**, of the supporting mesh **32**. As the leakage resistance is reduced, that is as the X-ray intensity increases, the surface potential of the photoconductive layer and the potential of the storage mesh **32** becomes more nearly equal.

Each of the elemental areas of the storage surface **31** attains a potential dependent upon the intensity of the X-ray image over the portion thereof corresponding to the elemental area in question. The storage surface **31**, in other words, is charged to different potentials at various areas thereof, just as the object being radiographed has areas of different transparency to X-rays, and the X-ray shadow image is converted into an electron charge image on the storage surface. The amount of voltage change produced on a given storage surface element during the writing operation depends on the photoconductive material and the intensity of the X-ray image; the latter is a function of such factors as X-ray exposure time, X-ray tube voltage and current and the X-ray absorption of the objects being examined.

Where it is desired to read the storage information out of storage tube **10**, the target electrode potential is made more positive than the storage member mesh potential. When switch **40** is in the read position, designated as "R," a voltage source **38'** of opposite polarity to that of voltage source **38** is connected to target **27**. This voltage may have a value, for example, of 200 volts positive relative to the cathode. During the reading operation, switch **48** is in the position indicated as "R" and the blanking potential is removed from grid **16** of tube **10** so that the electron beam is turned on. To read out the stored information, the storage member mesh voltage is dropped to such a level as to cause uncharged areas of the storage surface **30** to attain a negative voltage sufficient to cut off an electron beam aimed at these areas. This may be accomplished when switch **45** is in the read position, indicated as "R," by means of a variable tap on battery **42**. Alternatively, a battery **42'** of smaller voltage rating than the battery **42** could have its ungrounded terminal connected through contact "R" to the mesh **32**, in the manner indicated in Fig. 2. If the mesh potential is, for example, 40 volts positive relative to the cathode during the erasing and writing operations and the maximum storage surface potential at the end of the writing period at areas corresponding to a maximum X-ray image intensity were 20 volts positive with respect to the cathode, the mesh potential would be reduced to a value of, say, fifteen volts positive with respect to the cathode during the reading operation, so that the entire storage surface potential becomes twenty-five volts more negative than during the writing operation; that is, the storage surface potential varies from —25 volts for uncharged areas to about —5 volts for maximum charge, with respect to the cathode.

Since the entire storage surface **31** is now negative, electrons attracted to target **27** by the accelerating field between storage member **28** and the target **27** are prevented from falling upon storage surface **31**, and thus altering the charge on said storage surface during the reading operation. As the constant current electron beam scans across the storage member **28**, the magnitude of the beam current passing any given area of the storage member is proportional to the charge on that area of the storage surface **31**. This current is received at target **27** and a signal output is developed across load resistor **50** connected in series with the target, as shown in Fig. 1. The number of electrons in the beam which reached the target, and, hence, the signal output level, will vary in accordance with the charge previously written on to the storage member by the X-rays impinging upon the storage surface.

The signal output voltage across resistor **50** may be amplified by means of a video amplifier **52** and is then applied to the control grid **54** of a viewing or monitor tube **55**. The monitor tube may be a conventional cathode ray tube having an electron gun **56**, including the aforesaid grid **54**, and having horizontal and vertical deflection coils **57** and **58**, respectively. In order to synchronize the deflection of the storage and monitor tubes **10** and **55**, the horizontal deflection coils **22** and **57** are connected in parallel across the horizontal sweep generator **24**, while the vertical deflection coils **23** and **58** are each connected to vertical sweep generator **25**.

In certain applications it may be desirable to view the X-ray image at more than a single location. In such applications, a plurality of monitor tubes may be connected in parallel, that is, the horizontal deflection coils and the vertical deflection coils of each monitor tube would all be connected to the horizontal and vertical sweep generators **24** and **25**, respectively, while the control grid of each monitor tube would be connected to the output of amplifier **52**.

Although the output signal in Fig. 1 is taken from target **27**, it is possible to remove the output signal from the storage member **28**, as shown in the modification of Fig. 2. The beam current during the reading operation is maintained constant. Consequently, most of the electrons which do not impinge upon the positive target electrode **27** will be collected by the conductive mesh **32** and an output signal may be derived across a resistor **50** in series with conductive mesh **32**.

The target **27** in Fig. 2 takes the form of a rectangular electrically-conductive plate spaced close to the face of the storage tube rather than a film deposited directly on the inner surface of the base of tube **10**, as in Fig. 1. It should be understood, however, that the target may be of the form shown in either Fig. 1 or 2 without changing the essential operation of the storage tube **10**.

The remainder of the system of Fig. 2 is identical to that of Fig. 1 with the obvious exception that resistor **50** in the target circuit is omitted.

Certain difficulties have been observed with a storage tube, such as shown in Figs. 1 and 2, that is, a switching transient is fed to the amplifier when the storage tube signal electrode or target **27** is switched from a negative potential, relative to the cathode, for writing to a positive potential for reading. To overcome this disadvantage, the storage tube may be modified by placing the storage material **30** on the side of the conductive mesh **32** directly facing the electron gun, as shown in Fig. 3. This does not interfere with reading out stored signals since the electron charge pattern on the storage surface during reading makes all areas on that surface negative with respect to the cathode and, consequently, the electron beam cannot strike the storage surface **31**. With the storage surface facing the electron gun, the signal electrode or target potentials need not be switched in polarity between the writing and reading operations, but can be kept at a fixed positive potential throughout the operating cycle. That is to say, that a single voltage source **38** of fixed polarity may be used during all positions of switch **40**. Reversing the position of storage material on the storage mesh, as shown in Fig. 3, has still another advantage beside eliminating the switching transient in the signal output. A focussed electron spot passing through an aperture into a retarding field, as in the erasing operation, will be increased considerably in diameter by the time it has returned to the plane of the aperture and the resolution is thus decreased. Since the electron beam impinges directly upon the storage surface, in the modification of the storage tube shown in Fig. 3, the resolving power is greatly improved.

This invention is not limited to the particular details of construction, materials and processes described, as many equivalents will suggest themselves to those skilled in the art. For example, the output signal may be derived either from the target or from the storage member regardless of the side of the storage member upon which the photoconductive layer of storage material is deposited. It is accordingly desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What is claimed is:

1. In a system for storing an X-ray shadow image after exposure of an object to be examined by X-rays, a storage electron discharge device including an electron beam producing means, a storage member spaced from said beam producing means and comprising an electrically-conductive screen carrying a storage layer of electrically-insulating material whose electrical resistivity is dependent upon the intensity of X-radiation incident thereon, means for scanning said beam past the storage layer during controlled intervals, means for exposing a surface of said storage layer to said shadow image while said electron beam is disabled for altering the volume-conductivity of said layer and consequently the charge pattern stored on the exposed surface of said layer in correspondence with the intensity of said shadow image, an output circuit disposed in circuit with said storage member in which an output signal is derived during the period of beam scanning following exposure of said object to X-rays, the portion of the electron beam collected by said storage member during scanning of said beam after exposure of said object to said X-rays has been terminated being dependent upon the charge pattern of said storage layer, all portions of said surface of said storage layer repelling electrons in said electron beam for preventing said electrons from impinging upon said surface.

2. In a system for storing an X-ray shadow image after exposure of an object to be examined by X-rays, a storage electron discharge device including an electron beam producing means, a storage member spaced from said beam producing means and comprising an electrically-conductive screen carrying a storage layer of electrically-insulating material whose electrical resistivity is dependent upon the intensity of X-radiation incident thereon, said storage layer being composed of a material containing atoms of relatively high atomic number, means for scanning said beam past the storage layer during controlled intervals, means for exposing a surface of said storage layer to said shadow image while said electron beam is disabled for altering the volume-conductivity of said layer and consequently the charge pattern stored on the exposed surface of said layer in correspondence with the intensity of said shadow image, an output circuit disposed in circuit with said storage member in which an output signal is derived during the period of beam scanning following exposure of said object to X-rays, the portion of the electron beam collected by said storage member during scanning of said beam after exposure of said object to said X-rays has been terminated being dependent upon the charge pattern of said storage layer, all portions

of said surface of said storage layer repelling electrons in said electron beam for preventing said electrons from impinging upon said surface.

3. In a system for storing an X-ray shadow image after exposure of an object to be examined by X-rays, a storage electron discharge device including an electron beam producing means, a storage member spaced from said beam producing means and comprising an electrically-conductive screen carrying a storage layer of electrically-insulating material whose electrical resistivity is dependent upon the intensity of X-radiation incident thereon, means for scanning said beam past the storage layer during controlled intervals, means for exposing a surface of said storage layer to said shadow image while said electron beam is disabled for altering the volume-conductivity of said layer and consequently the charge pattern stored on the exposed surface of said layer in correspondence with the intensity of said shadow image, an output circuit connected to said storage member in which an output signal is derived during the period of beam scanning following exposure of said object to X-rays, the portion of the electron beam collected by said storage member during scanning of said beam after exposure of said object to said X-rays has been terminated being dependent upon the charge pattern of said storage layer, all portions of said surface of said storage layer repelling electrons in said electron beam for preventing said electrons from impinging upon said surface.

4. In a system for storing an X-ray shadow image after exposure of an object to be examined by X-rays, a storage electron discharge device including an electron beam producing means, an apertured storage member spaced from said beam producing means and comprising an electrically-conductive screen carrying a storage layer of electrically-insulating material whose electrical resistivity is dependent upon the intensity of X-radiation incident thereon, means for scanning said beam past the storage layer during controlled intervals, means for exposing a surface of said storage layer to said shadow image while said electron beam is disabled for altering the volume-conductivity of said layer and consequently the charge pattern stored on the exposed surface of said layer in correspondence with the intensity of said shadow image, an output circuit connected to said storage member in which an output signal is derived during the period of beam scanning following exposure of said object to X-rays, means for producing an accelerating field in the vicinity of said storage member for allowing electrons from said scanning beam to penetrate the apertures in said storage member after exposure of said object to said X-rays has been terminated, the number of electrons penetrating the storage member being dependent upon the charge pattern of said storage layer, all portions of said surface of said storage layer repelling electrons in said electron beam for preventing said electrons from impinging upon said surface.

5. In a system for storing an X-ray shadow image after exposure of an object to be examined by X-rays, a storage electron discharge device including an electron beam producing means, a storage member spaced from said beam producing means and comprising an electrically-conductive screen carrying a photoconductive storage layer of electrically-insulating material whose electrical resistivity is dependent upon the intensity of X-radiation incident thereon, means for scanning said beam past the storage layer during controlled intervals, means for exposing a surface of said storage layer to said shadow image while said electron beam is disabled for altering the volume-conductivity of said layer and consequently the charge pattern stored on the exposed surface of said layer in correspondence with the intensity of said shadow image, an output circuit connected to said storage member in which an output signal is derived during the period of beam scanning following exposure of said object to X-rays, the portion of the electron beam collected by said storage member during scanning of said beam after exposure of said object to said X-rays has been terminated being dependent upon the charge pattern of said storage layer, all portions of said surface of said storage layer repelling electrons in said electron beam for preventing said electrons from impinging upon said surface, and at least one visual indicating electron discharge device having beam deflection means synchronized with the beam scanning means of the storage device and having control means responsive to said output signal for providing a visual display representative of said X-ray shadow image.

6. In a system for storing an X-ray shadow image after exposure of an object to be examined by X-rays, a storage electron discharge device including a target electrode adjacent one end thereof, an electron beam producing means including a cathode and positioned at the other end of said discharge device, a storage member comprising an electrically-conductive screen carrying a photoconductive storage layer of electrically-insulating material whose electrical resistivity is dependent upon the intensity of X-radiation incident thereon, means for scanning said beam past the storage layer during controlled intervals, means for exposing a surface of the storage layer to said shadow image while said electron beam is disabled for altering the volume-conductivity of said layer and consequently the charge pattern written on said storage surface in correspondence with the intensity of said shadow image, an output circuit connected to said target electrode in which an output signal is derived during the period of beam scanning following exposure of said objects to X-rays, the portion of the scanning electron beam reaching said target electrode after exposure of the object to X-rays has been terminated being in accordance with the charge pattern previously written on said storage surface, all portions of said storage surface repelling electrons of said electron beam for preventing said electrons from impinging upon said surface.

7. In a system for storing an X-ray shadow image after exposure of an object to be examined by X-rays, a storage electron discharge device including a target electrode adjacent one end thereof, an electron beam producing means including a cathode and positioned at the other end of said discharge device, a storage member comprising an electrically-conductive screen carrying a photoconductive storage layer of electrically-insulating material whose electrical resistivity is dependent upon the intensity of X-radiation incident thereon, means for scanning said beam past the storage layer during controlled intervals, means for exposing a surface of the storage layer to said shadow image while said electron beam is disabled for altering the volume-conductivity of said layer and consequently the charge pattern written on said storage surface in correspondence with the intensity of said shadow image, an output circuit connected to said target electrode in which an output signal is derived during the period of beam scanning following exposure of said objects to X-rays, the portion of the scanning electron beam reaching said target electrode after exposure of the object to X-rays has been terminated being in accordance with the charge path previously written on said storage surface, all portions of said storage surface repelling electrons of said electron beam for preventing said electrons from impinging upon said surface and at least one visual indicating electron discharge device having beam deflection means synchronized with the beam scanning means of the storage device and having control means responsive to said output signal for providing a visual display representative of said X-ray shadow image.

8. In a system for storing an X-ray shadow image after exposure of an object to be examined by X-rays, a storage electron discharge device including a target electrode adjacent one end thereof, an electron beam producing means including a cathode and positioned at the other end

of said discharge device, a storage member comprising an electrically-conductive screen carrying on the side facing said target electrode a photoconductive storage layer of electrically-insulating material whose electrical resistivity is dependent upon the intensity of X-radiation incident thereon, means for scanning said beam past the storage layer during controlled intervals, means for exposing a surface of the storage layer to said shadow image while said electron beam is disabled for altering the volume-conductivity of said layer and consequently the charge pattern stored on the exposed surface of said layer in correspondence with the intensity of said shadow image, an output circuit connected to said storage member in which an output signal is derived during the period of beam scanning following exposure of said object to X-rays, the number of electrons penetrating said storage member and impinging upon said target electrode after exposure of said object to said X-rays has been terminated being dependent upon the charge pattern of said storage layer, all portions of said surface of said storage layer repelling electrons in said electron beam for preventing said electrons from impinging upon said surface.

9. In a system for storing an X-ray shadow image after exposure of an object to be examined by X-rays, a storage electron discharge device including a target electrode adjacent one end thereof, an electron beam producing means including a cathode and positioned at the other end of said discharge device, a storage member comprising an electrically-conductive screen carrying on the side facing said electron gun a photoconductive storage layer of electrically-insulating material whose electrical resistivity is dependent upon the intensity of X-radiation incident thereon, means for scanning said beam past the storage layer during controlled intervals, means for exposing a surface of the storage layer to said shadow image while said electron beam is disabled for altering the volume-conductivity of said layer and consequently the charge pattern stored on the exposed surface of said layer in correspondence with the intensity of said shadow image, an output circuit disposed in circuit with said storage member in which an output signal is derived during the period of beam scanning after exposure of said object to said X-rays has been terminated which is dependent upon the charge pattern of said storage layer, all portions of said surface of said storage layer repelling electrons in said electron beam for preventing said electrons from impinging upon said surface.

10. In a system for storing an X-ray shadow image after exposure of an object to be examined by X-rays, a storage electron discharge device including a target electrode adjacent one end thereof, an electron beam producing means including a cathode and positioned at the other end of said discharge device, a storage member comprising an electrically-conductive screen carrying on the side facing said target electrode a photoconductive storage layer of electrically-insulating material whose electrical resistivity is dependent upon the intensity of X-radiation incident thereon, means for scanning said beam past the storage layer during controlled intervals, means for exposing a surface of the storage layer to said shadow image while said electron beam is disabled for altering the electrical resistivity of said layer and consequently the charge pattern stored on the exposed surface of said layer in correspondence with the intensity of said shadow image, an output circuit disposed in circuit with said storage member in which an output signal is derived during the period of beam scanning after exposure of said object to said X-rays has been terminated which is dependent upon the charge pattern of said storage layer, all portions of said surface of said storage layer repelling electrons in said electron beam for preventing said electrons from impinging upon said surface, and at least one visual indicating electron discharge device having beam deflection means synchronized with the beam scanning means of the storage device and having control means responsive to said output signal for providing a visual display representative of said X-ray shadow image.

References Cited in the file of this patent

UNITED STATES PATENTS

2,169,840	Lewis	Aug. 15, 1938
2,203,347	Batchelor	June 4, 1940
2,442,287	Edwards	May 25, 1948
2,550,316	Wilder	Apr. 24, 1951
2,699,512	Sheldon	Jan. 11, 1955
2,739,258	Sheldon	Mar. 20, 1956
2,747,131	Sheldon	May 22, 1956
2,747,132	Sheldon	May 22, 1956
2,775,719	Hansen	Dec. 25, 1956

FOREIGN PATENTS

604,198	Great Britain	June 30, 1948