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X-Ray Irradiation Apparatus in Which an X-Ray Source is Energized Upon the Recording of Irradiation Dosage Data

George S. Hurst
University of Kentucky

Norbert Thennard
University of Kentucky

Karl A. Schneider
University of Kentucky

United States Patent

Hurst et al.

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[54] **X-RAY IRRADIATION APPARATUS IN WHICH AN X-RAY SOURCE IS ENERGIZED UPON THE RECORDING OF IRRADIATION DOSAGE DATA**

[72] Inventors: **George S. Hurst; Norbert Thennard; Karl A. Schneider,** all of Lexington, Ky.

[73] Assignee: **The University of Kentucky Research Foundation,** Lexington, Ky.

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[52] **U.S. Cl.** .....**250/65 R,** 250/67, 250/83.6 R, 250/93, 250/95, 250/98

[51] **Int. Cl.** **G03b 41/16,** H05g 1/44, H05g 1/28

[58] **Field of Search** 250/95, 67, 93

[56] **References Cited**

UNITED STATES PATENTS

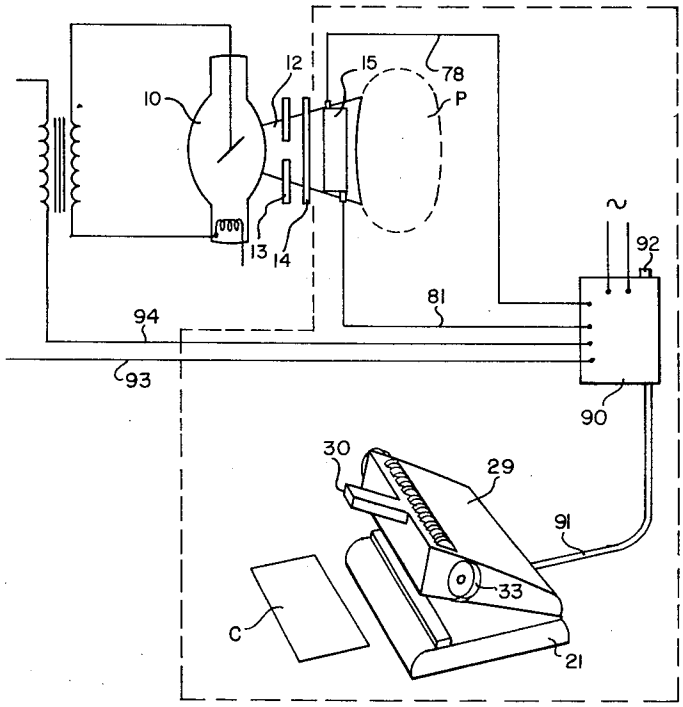
2,494,155	1/1950	Bastin	250/67
2,571,009	10/1951	Brown	250/86
2,796,527	6/1957	Oosterkamp	250/95
2,883,554	4/1959	Reed	250/95
2,899,582	8/1959	Hermsen	313/93

Primary Examiner—James W. Lawrence
Assistant Examiner—C. E. Church
Attorney—William E. Sherwood

[57] **ABSTRACT**

Apparatus for use in examining or treating patients with X-radiation or the like requires the making of a permanent record of the radiation applied. The operation of the radiation source is controlled in dependence upon the making of the record and the to radiation, or dose exposure is limited to a predetermined amount. A method is disclosed for safeguarding the patient and for producing a tangible record of the dose to which the patient is subjected.

15 Claims, 7 Drawing Figures



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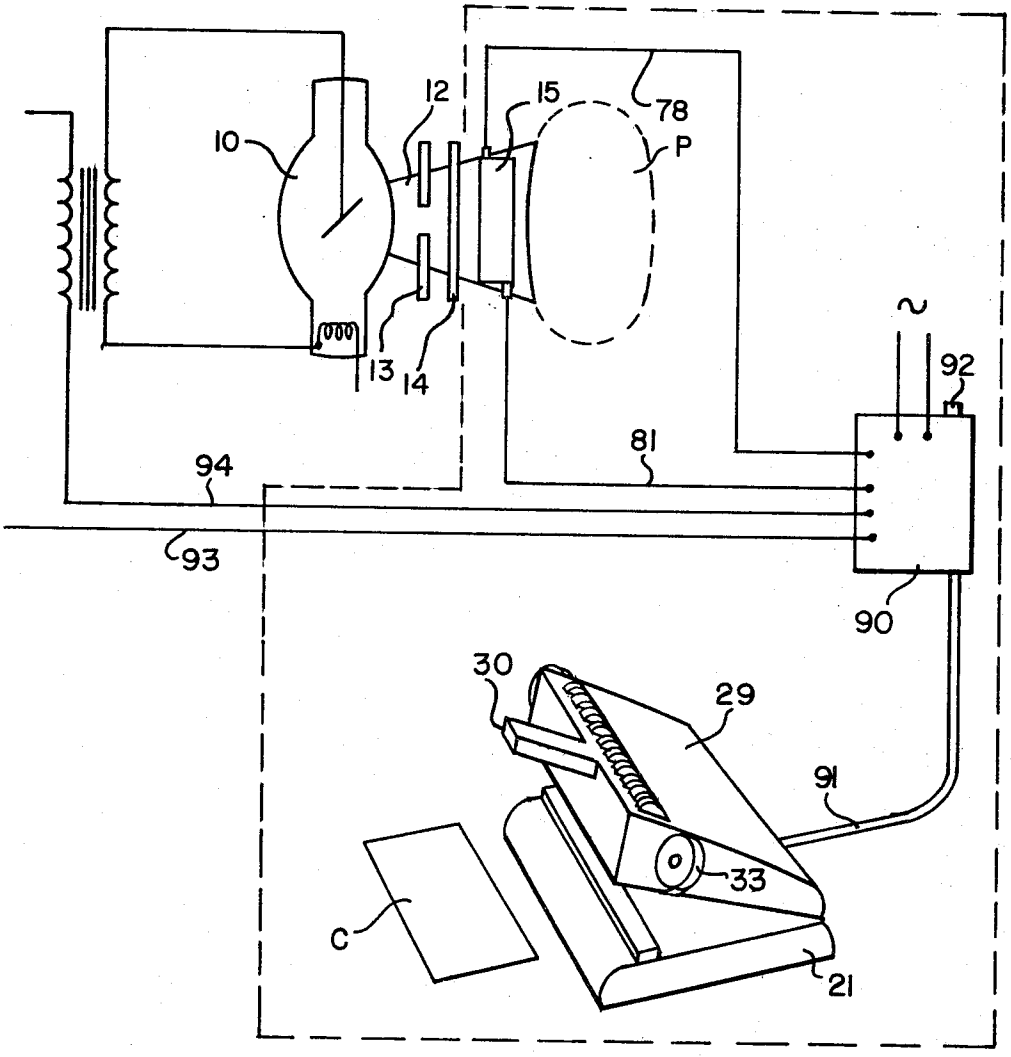

FIG. 1

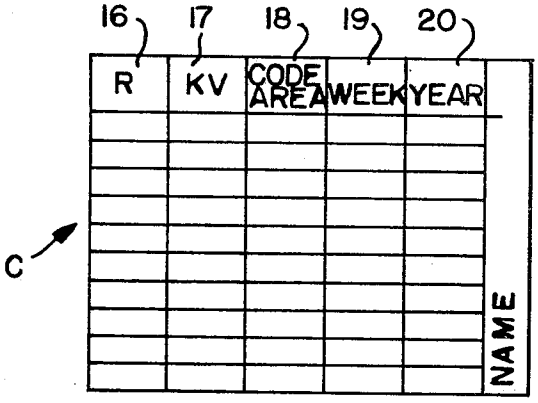

FIG. 2

INVENTORS
GEORGE S. HURST
BY NORBERT THONNARD
KARL A. SCHNEIDER
W. E. Sherwood
attorney

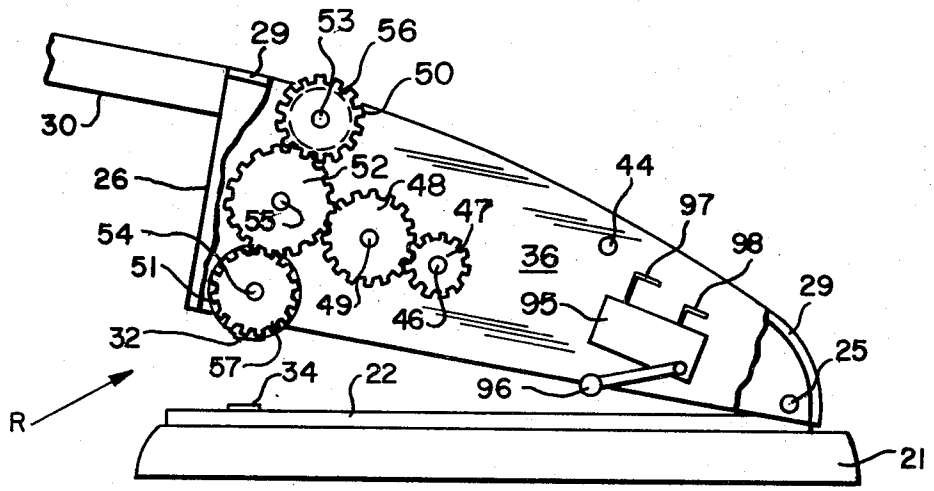

FIG. 4

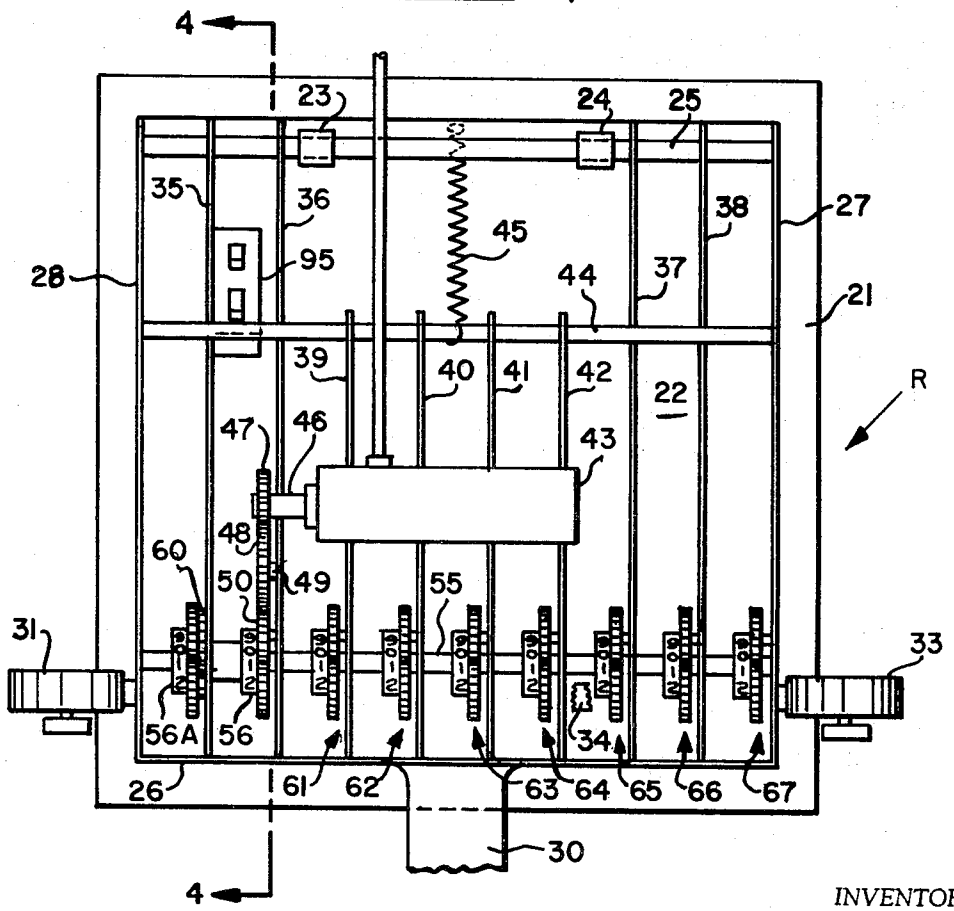

FIG. 3

INVENTORS
GEORGE S. HURST
BY NORBERT THONNARD
KARL A. SCHNEIDER
W. E. Sherwood
Attorney

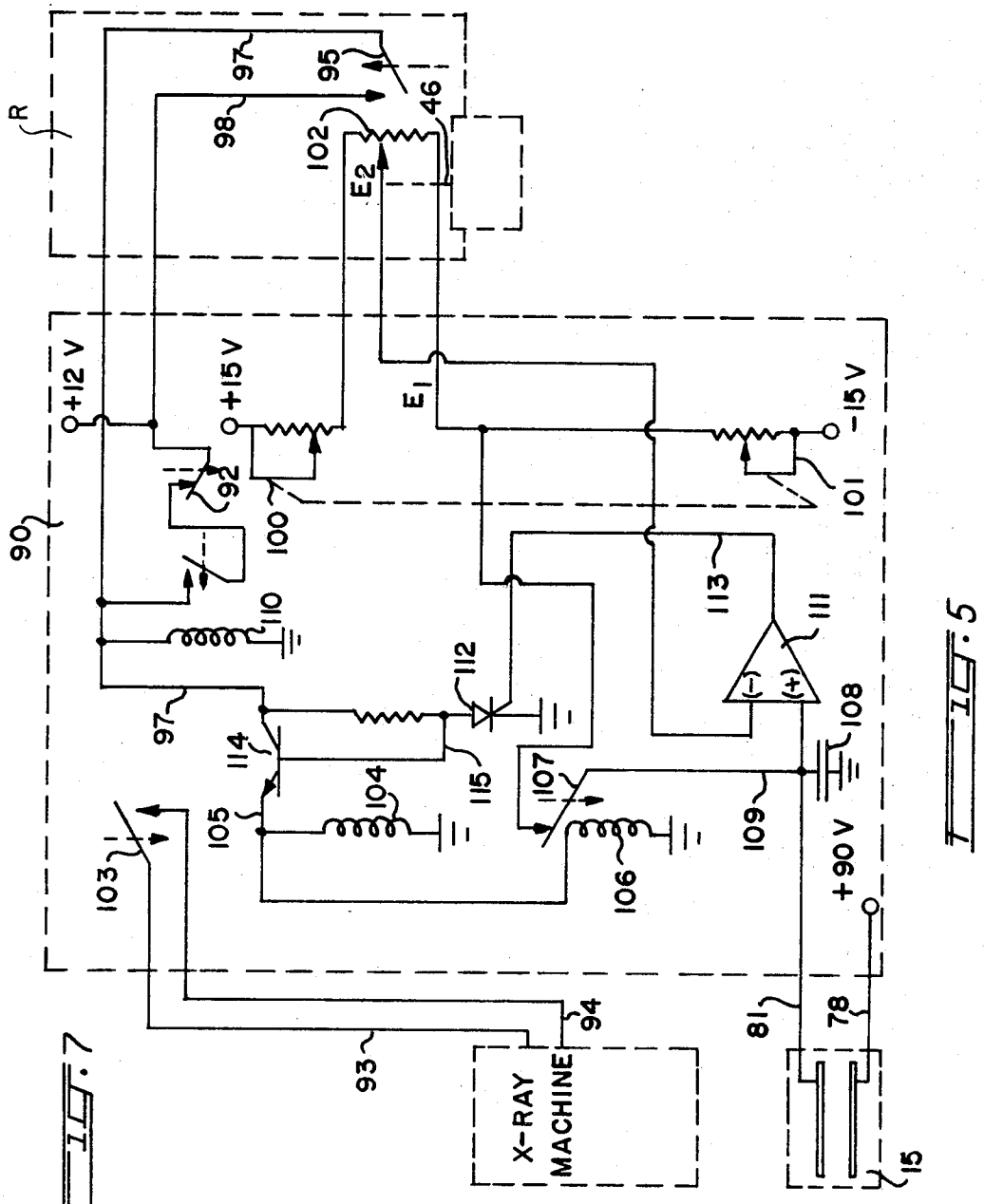

FIG. 5

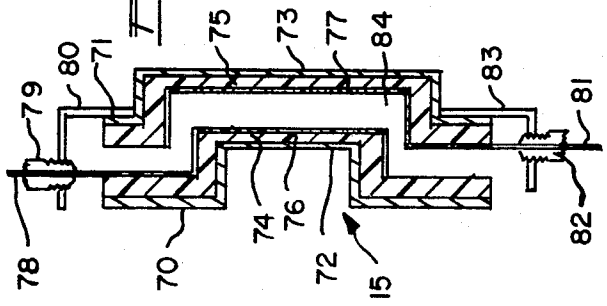

FIG. 7

INVENTORS
GEORGE S. HURST
NORBERT THONNARD
KARL A. SCHNEIDER
BY
W. E. Sherwood
ATTORNEY

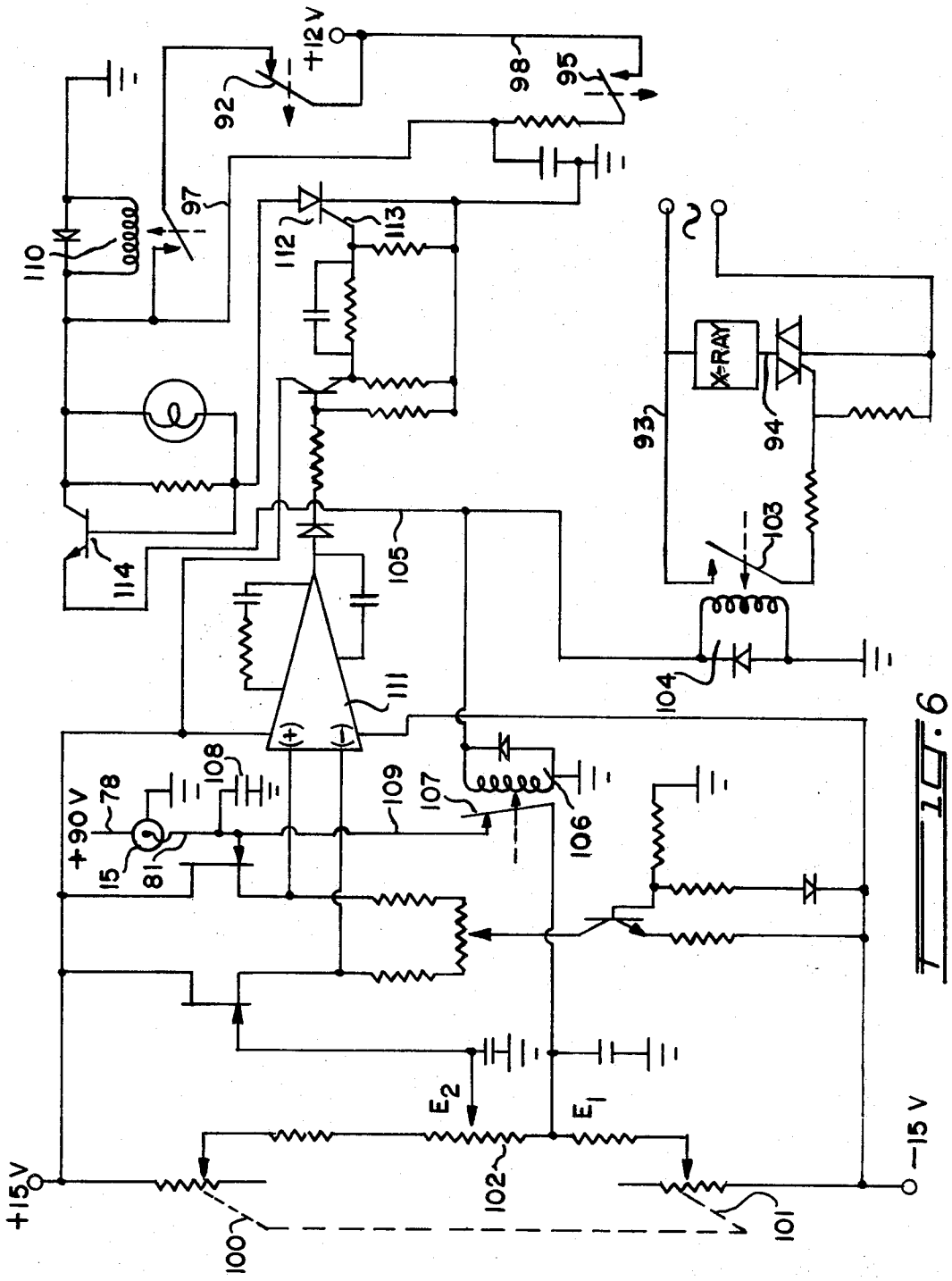

FIG. 1

INVENTORS

GEORGE S. HURST
NORBERT THONNARD
KARL A. SCHNEIDER

BY W. E. Sherwood
ATTORNEY

X-RAY IRRADIATION APPARATUS IN WHICH AN X-RAY SOURCE IS ENERGIZED UPON THE RECORDING OF IRRADIATION DOSAGE DATA

BACKGROUND OF THE INVENTION

Increasing awareness of the hazards associated with the exposure of humans to ionizing radiation has resulted in the establishing of certain safeguards which are expected to be observed by doctors and dentists in the treatment of their patients when employing X-ray apparatus or other sources of such radiation. However, in treating a patient the dentist, for example, has no way of judging the cumulative effect of prior radiation doses to which a patient may have been subjected by prior treatments from other dentists or doctors. Unlike workers in controlled areas requiring the wearing of dosimeter badges or the like, the average patient, who over a period of years may receive random radiation doses from dental treatments, medical diagnostic or therapy treatments or the like from different dentists, doctors, or institutions, has no personal record of his prior exposures.

A need accordingly exists for a suitable record, for example, a simple card which an individual may retain in his possession and which would reflect such information as the dates on which he has received a treatment, the coded location of the part of his body which was treated, the dose data, and similar relevant information. Having available such information, the dentist or physician could better judge the acceptable levels of radiation dose to give the patient.

However, even the benefit of this concept would be decreased if erroneous entries are made on the patient's record, or if an entry, which should be made, is for some reason omitted. The present invention overcomes this problem by requiring the making of a permanent record for the patient's possession, and, if desired, a similar record for the dentist's possession, and in the making of such record requires that the dosage be suitably limited to an amount of exposure predetermined by that dentist. As will be apparent, the practice of the invention moreover serves to protect the dentist from any unwarranted claims of malpractice or the like, since the radiation source cannot be operated without an accurate associated record of the exposure data being made.

Various general suggestions in the prior art, such as Brown U.S. Pat. No. 2,571,009, have been made regarding the controlling of an X-ray machine by insertion of an exposure-indicating template for a given individual into the electrical circuit of the machine. However, such an arrangement gives no direct information on the exposure to radiation actually received by the patient. For example, if the timer for the generator, or the anode potential, or the cathode excitation of the Brown machine are not precisely calibrated, the patient may receive various doses. As will be further noted, the Brown disclosure deals with a method of recording X-ray machine control settings, and is in no way related to the direct control and recording of the amount of exposure dose. Moreover, in a method such as contemplated by the Brown patent, no personal record which is to be given to, and retained by the patient, is intended.

It is these and other disadvantages of conventional methods and apparatus for applying exposures to ionizing radiation, which it is a purpose of our invention to overcome.

SUMMARY OF THE INVENTION

The method involves the determining of the dose to be given to a patient, based upon knowledge of the previous doses to which the patient has been subjected, followed by the manual setting of a recording means to correspond to the so-determined dose. The recording means is then operated to produce a permanent record and the operation of the recording means initiates the operation of the radiation source. The step of setting the recording means in turn establishes a limit to the amount of radiation to be received by the patient, and when this limit is reached the radiation source is automatically inactivated.

The apparatus includes means for adjustably setting and recording the amount of radiation exposure to be employed, the making of a coded record of the part of the body being irradiated, the date of the treatment, and such other data as may be established by the medical or dental professions. Among the objects of the invention are the provision of a method for operating a radiation source only when a permanent record of its operation is being produced; the provision of an improved control and recording apparatus for use with conventional X-ray machines; the provision of an apparatus which may serve as an adaptor for conventional X-ray machines without modifying such machines; the provision of an apparatus arranged to prevent accidental repetitive operation of an X-ray machine; the provision of an improved ionization chamber for use in medically related radiation practices; the provision of a permanent record produced upon the operation of an X-ray machine, and the provision of a new practice of protecting the health of patients undergoing treatment or examination with ionizing radiation.

These and other objects and advantages of the invention will become more apparent as the description proceeds and when considered in conjunction with the accompanying drawings in which

FIG. **1** is a schematic view of the adaptor shown in operative relationship to an X-ray generator and being indicated by the dotted line enclosure.

FIG. **2** is a plan view of a suitable identification card for recording the dosage and for personal retention by the patient.

FIG. **3** is a top plan view of the adjustable recorder with the cover removed therefrom and with parts broken away.

FIG. **4** is a side elevation view of the recorder in normal position with parts broken away and indicating the gear relationship as seen along line **4**—**4** of FIG. **3**.

FIG. **5** is a system block diagram for the apparatus.

FIG. **6** is a diagram of the control circuit for the apparatus; and

FIG. **7** is an exploded view of the ionization chamber.

Referring now to FIG. **1** and as a further background of the invention, conventional X-ray generators represent a substantial investment for the owner and while the apparatus of the present invention may be incorporated into the generator by the manufacturer thereof, it may equally well be used as a kit or adaptor for installation on existing machines. Such conventional machines employ a radiation source-controlling switch in the circuit leading to the tube **10** and with this switch being opened to inactivate the generator when the desired exposure has been given to the patient. Such a switch may be opened manually, or otherwise. Accordingly, it is a feature of the invention that without requiring expensive modification of existing equipment, or purchase of a new generator, the dentist or doctor may employ the present adaptor to control the operation of his already-owned generator. Moreover, on conventional machines a suitably shielded cone **12** having means **13** for providing an adjustable collimating aperture, and for insertion of a selected filter **14**, are usually provided. The present apparatus differs from the usual machine in that the cone must also provide for a dosimeter such as the ionization chamber **15**, later to be described, and accordingly will represent an additional, but comparatively small expense to the owner while making use of the invention with his existing machine.

The invention requires that a permanent record, which may be retained by the patient, and/or for example, by the dentist, be made each time the generator is activated. The particular form of such recording may vary and may comprise the printing of a card C, the storing of information on a film, tape or the like, or other equivalent means of recording such information. For example, a card C such as indicated in FIG. **2** is preferred and may include space for the patient's name and columnar rows **16** to **20** in which are printed the data relating respectively to doses expressed in roentgens and fractions thereof; kilovoltage of the generator circuit; a coded symbol representing the irradiated area of the body; the week of the calendar year; and the year in which the exposure was

sustained. Such a record, of course, need not be a card provided only for the patient, but may also include a retrievable record kept by the dentist in the recorder itself, or may be a duplicate carbon of the patient's card, a photocopy of the same, a punched record, or the like.

Referring now to FIGS. 3 and 4, one suitable form of adjustable recorder R for use with the described card C comprises a sturdy base member 21 supporting thereabove a flat plate 22 and having brackets 23, 24 adjacent its rear and in which an elongated rod 25 is mounted. Mounted for pivotal movement about the axis of rod 25 is a housing including a front wall 26, side walls 27, 28 and a top cover member 29 having apertures therein for access to certain gearing, later to be described. A forwardly projecting simple handle 30 is attached to the housing for manual actuation at the time the generator is to be activated, although, as will be understood, the actuation may be accomplished by any other means such as a remotely controlled push button.

A supply reel 31 of inked tape 32 is mounted on the outer side of wall 28 and feeds such tape to a similar take-up reel 33 mounted on the opposite wall 27 and with the tape being disposed between the housing and a suitable resilient pad 34 extending across plate 22. Contained within the housing and attached to front wall 26 is a plurality of parallel, thin, gear-supporting plates the number of which is dependent upon the number of data units or digits, to be recorded. Certain plates as indicated at 35, 36, 37 and 38 are longer than the companion plates 39, 40, 41 and 42 which assist in mounting of the potentiometer 43, but all plates are so mounted as to be rigid and to retain their proper spacing. A stationary rod 44 extending between the side walls of the housing engages with all plates, and the longer plates at their rearward ends also are attached to pivot rod 25. Extending between the base 21 and rod 44 is a tension spring 45 serving to keep the housing in elevated position until it is deliberately lowered in order to provide a printed record and thereby to activate the electrical circuit which will close the switch of the X-ray machine.

The potentiometer 43 may be of any suitable type, such as the Spectrol Model 126, 5,000-ohm, 10-turn unit available from Newark Electronics, Newark, N.J., and includes a shaft 46 projecting from one end thereof and journalled for rotation in plate 36. The shaft carries a small gear 47 in engagement with an idler gear 48 (FIG. 4) mounted on stub shaft 49. A main gear train comprising an upper small gear 50 and a lower small gear 51 of equal size, both of the smaller gears being meshed with a larger intermediate gear 52 which, in turn, is in mesh with idler gear 48, serves to adjust the position of the potentiometer shaft 46. For enabling this adjustment the periphery of the upper gear 50 extends through a suitable slot in the cover plate 29, and the small gears 50 and 51 are suitably mounted on the respective stub shafts 53, 54 journalled in plate 36. A rod 55 extending between walls 27, 28 of the housing serves to support the larger gear 52 for free turning movement thereon, as well as the larger gears of the companion gear trains later to be described.

Attached to the upper gear 50 is an indicating disc 56, the periphery of which is visible through the cover plate aperture and which includes ten equally spaced numerals reading from zero to nine. Similarly, a printing disc 57 is attached to lower gear 51 with a diameter greater than that of gear 51 and with its periphery having equally spaced raised numerals reading from zero to nine. The gear ratios and spacings of numerals on the respective discs are such that when the dentist views a given numeral through the housing cover the equivalent numeral on the printing disc is in position for printing.

By means of a conventional tenfold odometer drive generally indicated at 60 and actuated by the adjusting of the gear 50 by the dentist, a companion gear train supported upon plate 35 and rod 55 is adjusted to cause the indicating disc 56A to move one-tenth of a rotation when indicating disc 56 moves a full rotation, or to cause disc 56 to make a full rotation when disc 56A makes one-tenth of a rotation. This companion gear train, of course, includes upper and lower small gears and an intermediate larger gear, all of the same size and ratios as the described main gear train, but does not include the equivalents of gears 47, 48 found in the main gear train. In passing, it may be noted that in a typical usage of the invention, the disc 56A may be indicating a dose expressed in roentgens and disc 56 will then be indicating tenths of roentgens.

For the purpose of providing information other than the selected adjustment of the potentiometer, a series of other gear trains which may be set independently, are provided. These trains include only the upper and lower small gears with their attached indicating and printing discs, and with the accompanying larger intermediate gear which is journalled on the rod 55. As an example, the gear trains indicated generally at 61, 62 may give a two digit kilovoltage printout corresponding to the voltage reading which the dentist intends to use during the exposure; the trains indicated at 63, 64 may give a coded two digit symbol indicative of the area of the body which is to be exposed to radiation; the two trains indicated at 65, 66 may give a two digit printout corresponding to the week of the year; and the train indicated at 67 may give a reading corresponding to the last numeral of the year, it being understood that if more information is required, additional such trains would be provided in the recording apparatus.

In order to compensate for gear backlash, any suitable means, not shown, such as detents, spring devices, or the like may be used to insure proper printing register of the selected numeral on a printing disc with respect to the corresponding selected numeral on its associated indicating disc.

In accordance with professional knowledge in the fields of health physics and radiation protection, the ionization chamber now to be described requires a design which can be calibrated in roentgens (or fractions thereof) of exposure and which chamber construction will avoid excessive X-ray absorption and scattering. Ionization chambers employed essentially in the protection of the X-ray tube, as for example in the Reed Pat. No. 2,883,554, have been suggested, but do not require the special characteristics of the dosimeter used in the present invention. Referring now to FIG. 7, we employ a chamber comprising a pair of juxtaposed suitably-grounded plates providing structural strength and having relatively thick annular portions 70 and 71 and with central window portions closed by thin sheets 72, 73 which, for example, may be of a suitable low atomic weight material such as aluminum and with a thickness of about 0.010 inch. Layers 74, 75 of a low atomic weight insulating material such as plastic are affixed to the inner surfaces of the plates. A layer 76 of conducting material of low atomic weight, such as an evaporated film of aluminum with a thickness less than that of window 72, is supported upon the insulating layer 74, and a similar conducting layer 77 is supported upon the other insulating layer 75. A conductor 78 extends from layer 76 and may conveniently be supported by an insulator 79 attached to a bracket 80 on the companion plate and a similar conductor 81 extends from layer 77 and is supported by an insulator 82 attached to the bracket 83. These insulators preferably have dimensions suitable for mounting of the assembled chamber in the cone 12 (FIG. 1). As will be understood, when the chamber is assembled by drawing the parts together by any suitable fastening means (not shown) the two inner conducting layers 76, 77 are insulated from each other and a suitable thin space 84 is provided in the interior of the assembly. This space may be filled with any suitable gas, for example, dry air or dry nitrogen at atmospheric pressure.

The described construction has been found to provide a dosimeter 15 particularly useful in the practice of the invention and is readily calibrated either from accepted calculations or by use of another dosimeter as a standard, as for example by using the well known Victoreen chamber as such a standard. Calibration may be accomplished in terms of the actual dose in roentgen units or of the absorbed dose in rad units, according to the definition of these terms adopted by the International Commission on Radiological Units and Measurements.

Passing now to FIG. 1 the recording device preferably is physically displaced from a control box **90** in which a conventional power supply pack is housed and which pack is fed from a 60-cycle source of power. An elongated cable **91** extends between the recorder and control box and contains certain potentiometer leads and leads from a microswitch now to be described. Also mounted on the control box is a manually operable reset switch **92** which cannot be inadvertently operated during the handling of the recorder. The dosimeter conductors **78, 81** and a pair of conductors **93, 94** leading to the circuit of the X-ray machine also extend from the control box.

Reverting now to FIGS. **3** and **4**, a conventional recorder-operated microswitch **95** is mounted upon one of the larger plates, for example, plate **35**, of the recorder and has an arm **96** which closes a circuit through leads **97, 98** only when that arm is suitably engaged by card C in its proper position on the plate **22** of the recorder.

As indicated in FIG. **5**, adjustable resistors **100, 101**, which are ganged, set the total voltage across the resistance **102**. This setting of the total voltage is performed in an initial calibration procedure in which a technician adjusts the intended radiation exposure levels to the numbers indicated by discs **56** and **56a**. Moreover, as the dentist during later use manipulates these discs and associated gear trains which rotate shaft **46** of potentiometer **43** in FIG. **3** (resistance **102** in FIG. **5**) the gears at the same time prepare for the print out of the values of the determined dose. These values will be printed in column **16** of card C in terms of roentgens and fractions of roentgens. Accordingly, as the housing of the recorder is lowered after the dentist has made this setting, the microswitch **95** then closes, and provided that the normally closed reset switch **92** had been previously momentarily opened, the record will be made on the card and the X-ray generator will be operated in the manner now to be described.

For adapting the invention to a conventional X-ray generator a rapid-acting, source-controlling switch **103** shiftable between two positions which respectively energize and de-energize that generator is provided, and the leads **93, 94** from this switch may be connected in any suitable arrangement into the operating circuit of such generator. The switch **103** preferably is operated by relay **104** fed from conductor **105** and this conductor **105** also feeds a relay **106** adapted to operate rapid-acting switch **107**, which is connected to an integrating capacitor **108** by a conductor **109**. This capacitor also is connected to the ionization chamber through conductor **81**. When power is first applied to the circuit by closing of micro-switch **95**, and subsequent to a momentary opening of reset switch **92** by the dentist, a rapid-acting relay **110** is energized. At this time the voltage E_2, representing the crossover voltage as determined by the setting of resistance **102**, is greater than E_1. The output of the operational amplifier **111** accordingly is negative and the silicon-controlled-rectifier **112** connected to that amplifier by conductor **113** is non-conducting. However, the transistor **114** connected to the SCR by lead **115**, and to the switch **95** by lead **97**, and to relays **104** and **106** by lead **105**, is conducting and with the result that each of relays **104** and **106** are energized. Therefore, when power is applied the switch **103** shifts to energize the X-ray generator and switch **107** shifts to disconnect the capacitor **108** from the voltage E_1 and thus permits the capacitor to begin to charge up and to utilize the charge supplied to it from the ionization chamber.

When the voltage on the capacitor becomes greater than E_2, the output of amplifier **111** becomes positive and this in turn, renders SCR **112** conducting whereupon transistor **114** becomes non-conducting. When the transistor thus becomes non-conducting, the circuits to each of relays **104** and **106** are opened and the respective switches **103** and **107** are again shifted. Shifting of switch **103** serves to inactivate the X-ray generator and shifting of switch **107** serves to return the capacitor **108** again to voltage E_1.

As will be noted, the relay **110**, however, is still energized at this time (since SCR **112** remains conducting and the reset switch remains closed) even though the microswitch **95** is open. This serves as a step of automatically preventing a double exposure of the patient in case the recorder housing should inadvertently be lowered against the bias of its spring **45**. Only when the dentist momentarily and deliberately opens the reset switch **92** will the relay **110** become de-energized and the SCR **112** stop conducting. After opening of the reset switch the apparatus, of course, is in readiness for treatment of another patient in accordance with the described process.

As will now be apparent, the described apparatus enables the user of the X-ray machine to expose the patient to an ionizing radiation dosage which will be immediately terminated as soon as the capacitor is charged to a value corresponding to the setting of the recorder. It is within the purview of the invention to incorporate variable capacitors in the circuits as a substitute for the described capacitor **108** in order to achieve a wider range of exposures.

Whereas the arrangements shown in FIGS. **1** and **5** disclose the major components of the apparatus, it will be appreciated that within the control box **90**, numerous elements of the circuit are contained and which will be apparent to one skilled in the art, as for example, the various conventional resistance, capacitance and impedance elements shown in FIG. **6** and which require no explanation for an understanding of the invention. Suitable voltages, for example, provided by the power supply pack are indicated in FIG. **6** for example.

Having thus described our improved method for applying the recorded dose of ionizing radiation and having disclosed a preferred form of apparatus for use with the method, it will be understood that the apparatus of the invention may be embodied in other forms than that described as being the preferred form.

What is claimed is:

1. A method of applying a dose of ionizing radiation to a human subject from a radiation source comprising, determining the dose to be given to the subject in relation to the record of previous exposures of the subject to radiation doses and thereafter selectively setting the value of the determined dose on an adjustable dose-selecting device, recording the determined dosage-data in the form of a permanent record, initiating the flow of radiation from said source in dependence upon the making of said record, passing the radiation through a dosimeter prior to its reaching the subject and forming an electrical charge indicative of the dose of radiation received by the subject, and utilizing said charge to interrupt the flow of radiation to said subject when said charge reaches a value corresponding to the determined dose.

2. A method as defined in claim 1 including recording the data of said determined dose expressed in roentgens and fractions of roentgens as part of said permanent record.

3. A method as defined in claim 1 including recording of the voltage of the radiation source as part of said permanent record.

4. A method as defined in claim 1 including recording a coded symbol corresponding to the area of the body of the subject being irradiated as part of said permanent record.

5. A method as defined in claim 1 including recording the time at which said dose is given to said subject as part of said permanent record.

6. A method as defined in claim 1 including automatically preventing the application of a subsequent exposure of said subject to radiation following the application of said recorded dose and thereafter consciously cancelling the prevention of the application of a subsequent exposure.

7. A method defined in claim 1 wherein said recording comprises the printing of said permanent record.

8. Apparatus for applying a readily selectable recorded dose of ionizing radiation to a human subject comprising an electrical circuit including a source of radiation and a manually adjustable recorder, a source-controlling switch in said circuit shiftable between a first position deenergizing said source and

a second position energizing said source, circuit-controlling means operable upon the setting of said recorder for establishing the selected amount of radiation dose to be received by said subject, means between said source and said subject responsive to the amount of radiation dose received by said subject for shifting said switch to its first position, and means responsive to the forming of a permanent record by said recorder for shifting said switch to its second position.

9. Apparatus as defined in claim **8** wherein said circuit-controlling means includes a potentiometer mechanically connected to said recorder and adapted to control said electrical circuit in accordance with the setting of said recorder.

10. Apparatus as defined in claim **8** wherein said means responsive to the amount of radiation dose to be received by said subject includes a dosimeter interconnected with a capacitor in said circuit and adapted jointly to establish the time at which said switch is shifted to its first position.

11. Apparatus as defined in claim **8** including a recorder-operated switch in said circuit adapted to complete the circuit to said source-controlling switch when said recorder makes a record of said exposure.

12. In an apparatus for applying a recorded dose of ionizing radiation to a human subject and having a source of radiation controlled in dependence upon the recording of the dose and an ionization chamber interposed between said source and said subject, the improvement comprising an ionization chamber having juxtaposed support plates with thin central wall portions of low atomic weight material through which a beam of radiation passes, a layer of low atomic weight electrical insulating material affixed to the confronting inner surfaces of each of the plates, a thin layer of electrical conducting material on the confronting inner faces of each of said insulating layers and spaced from each other to provide a gas filled space therebetween, conductors extending from the respective layers of conducting material, and supporting bracket means on the exterior of said chamber attached to at least one of said plates for positioning said conductors, said plates being adapted to be secured to each other adjacent their peripheries.

13. Apparatus as defined in claim **12** wherein said insulating material comprises plastic material.

14. Apparatus as defined in claim **12** wherein each of said central wall portions comprises a relatively low atomic weight metal having a thickness of not more than about 0.010 inch.

15. Apparatus as defined in Claim **12** wherein the thickness of said conducting layers is less than the thickness of the corresponding central wall portions and of said insulating layers.

* * * * *