June 7, 1938. M. MORRISON 2,119,682

SYSTEM FOR PRODUCING X-RAY POTENTIAL HAVING PREDETERMINED WAVE FORM

Filed April 29, 1933

Fig. 1.

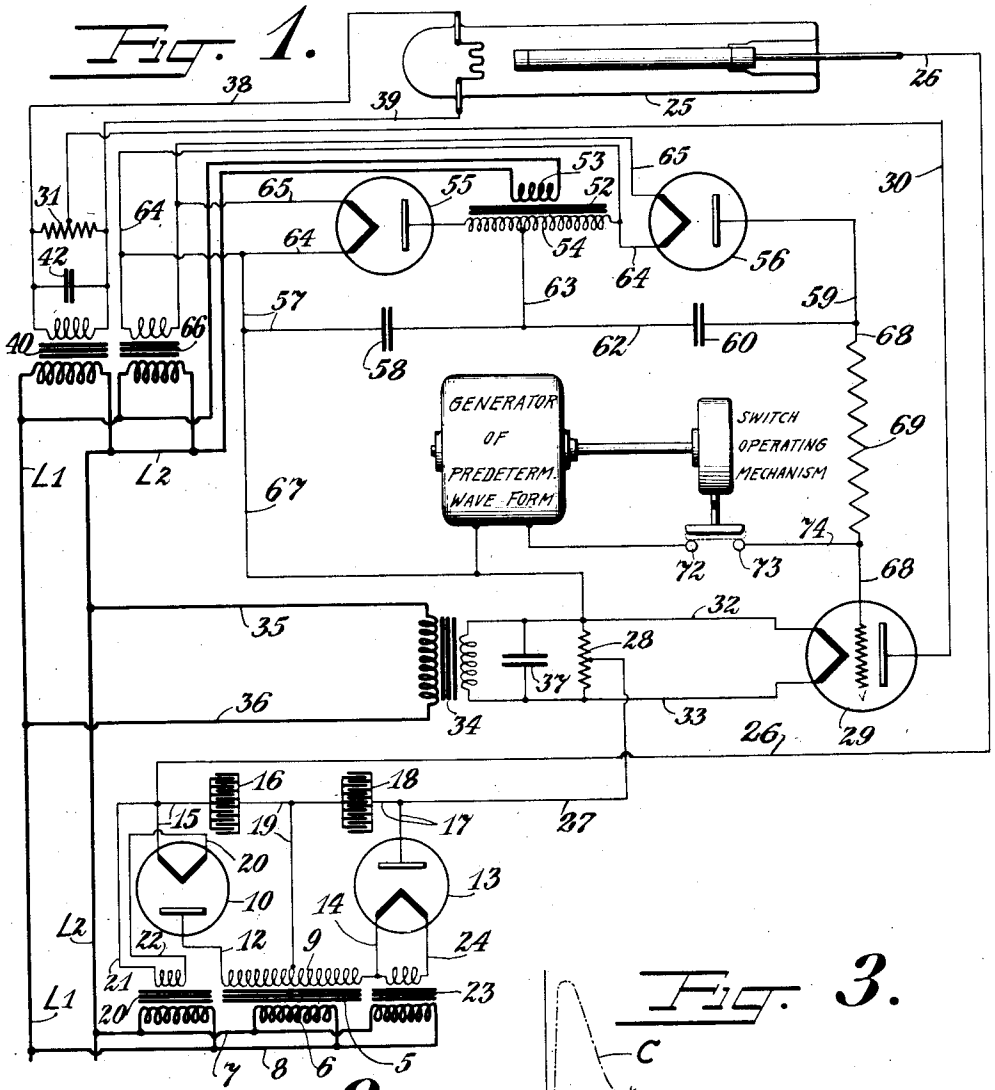


Fig. 2.

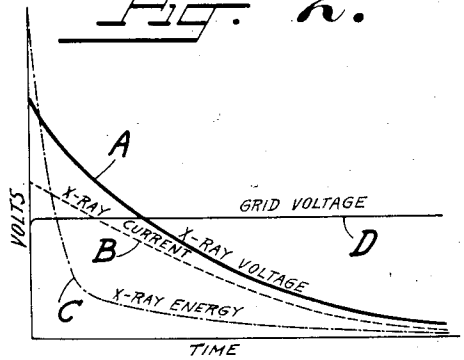
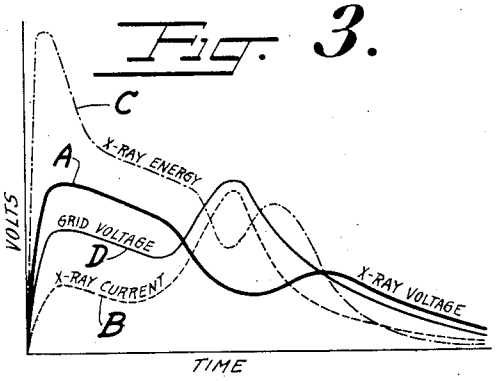


Fig. 3.



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SYSTEM FOR PRODUCING X-RAY POTENTIAL HAVING PREDETERMINED WAVE FORM

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Application April 29, 1933, Serial No. 668,505

13 Claims. (Cl. 250—34)

My invention relates to X-ray systems and particularly to such systems wherein the potential impressed upon the X-ray tube is given a predetermined wave form.

In generating X-rays for the purpose of taking radiographic exposures it has become generally well recognized that X-rays of different characteristics have under certain conditions greater beneficial results than under other conditions. This may be appreciated by considering that the body thickness of various patients differ with each individual thus necessitating X-rays of greater penetrative power with some patients than with others in order that the resulting photographic film may have the desired density and contrast.

In the utilization of X-rays for the purpose of taking radiographic images, particularly of parts of the human anatomy, I have found that certain forms of the voltage wave shape applied to the X-ray tube produce desirable results which are greatly advantageous over certain other wave forms for diagnostic purposes. Specific wave forms of X-ray tube applied voltage, I have found, produce better differentiating characteristics in the photographic image than others, making it possible, with certain predetermined forms of applied voltage wave, to make diagnoses which would be otherwise obscured. Broadly, the nature of my invention resides in an apparatus comprising means for preselecting the wave form of the X-ray tube applied voltage by an auxiliary control circuit which is electrically associated with the main discharge circuit, but my invention is more particularly described in the claims hereto appended.

As one specific embodiment of my invention I disclose herein its application to a condenser type of X-ray discharge circuit described in my prior application, Serial No. 582,933, filed December 24, 1931, and, in the present embodiment, I associate my control circuit with the main circuit by means of a three-electrode electron discharge tube.

My invention is not limited to any particular form of main discharge circuit and the one herein disclosed is used only as a means of illustrating one application of the broad aspect of the present invention. With my present invention after having once empirically determined the particular type of X-rays most advantageous for radiographic purposes for any given patient I can cause generation of these identical X-rays at any subsequent time, which have the same desired energy-wave length distribution without the necessity for experimentation, by modulating the high potential impressed upon the X-ray tube in a predetermined manner.

For a better understanding of my present invention reference may be had to the accompanying drawing wherein

Figure 1 is a diagrammatical illustration of an X-ray system constructed in accordance with my present invention;

Figure 2 is a diagrammatical representation graphically shown of the normal wave form of the discharge current and voltage, the grid voltage and X-ray energy in the usual condenser discharge system, and

Figure 3 is a graphic illustration of the wave form of the X-ray tube discharge current and voltage, the grid voltage, and the X-ray energy-wave length distribution, as a result of giving the potential impressed upon the X-ray tube a predetermined wave form in accordance with my present invention.

Referring now to the drawing in detail I have shown in Figure 1 a suitable source of alternating current of commercial potential, such as the conductors L1 and L2. A high tension transformer 5 is arranged to have its primary winding 6 supplied with energy from the source L1, L2, through a pair of conductors 7 and 8. A high tension secondary winding 9 of the transformer 5 is connected to the anode of a rectifying valve 10, by means of a conductor 12, and to the cathode of a similar valve tube 13, by means of a conductor 14.

The cathode of valve tube 10 is connected, by means of a conductor 15, to a condenser 16 and the anode of the rectifying valve 13 is similarly connected, by means of a conductor 17 to a condenser 18. These condensers are in turn connected by means of a conductor 19 which is also connected to the midpoint of the high tension secondary winding 9. The thermionic cathode of the valve tube 10 receives heating current from the secondary winding of a low tension transformer 20 through a pair of conductors 21 and 22. Similarly the cathode of valve tube 13 receives heating current from the secondary winding of a low tension transformer 23 through a pair of conductors, one of which may comprise the conductor 14 and the other a conductor 24. The primary windings of the respective transformers 20 and 23 receive energy from the source L1, L2, in any suitable manner, such as the conductors 7 and 8 which also supply energy from the source to the primary winding 6 of transformer 5.

Upon energization of the primary winding 6 from the source L1, L2 by closure of a suitable

switch (not shown) a high potential current will be induced in the secondary winding 9. This causes the current thus generated to flow through the respective valve tubes 10 and 13 to the condensers 16 and 18 during half waves of the alternating current cycle. This circuit may be traced from the secondary winding 9 by means of conductor 12, through the valve tube 10, conductor 15 to condenser 16 and thence back to the secondary winding 9 by means of conductor 19. In a similar manner current will flow by means of conductor 19 to condenser 18 and thence back to the secondary winding 9 by means of conductor 17, valve tube 13, and conductor 14. Accordingly the condensers 16 and 18 will accumulate a charge of high potential electrical energy.

An X-ray tube 25 has its anode connected to the conductor 15 and consequently to the condenser 16, by means of a conductor 26, and the conductor 17 and consequently the condenser 18 is connected, by means of a conductor 27, to the midpoint of a resistance element 28 connected in parallel with the cathode of a three electrode discharge device 29 which constitutes a high potential switch. The anode of this discharge device 29 is in turn connected, by means of a conductor 30, to the midpoint of a resistance element 31 connected in parallel with the cathode of the X-ray tube 25.

The cathode of the discharge device 29 receives heating current through a pair of conductors 32 and 33 from a low tension source, such as a transformer 34, the primary winding of which may be energized through conductors 35 and 36 from the commercial source L1, L2, and a condenser 37 is connected in a shunt circuit with this cathode and the secondary winding of the transformer 34 for a purpose to be hereinafter more fully explained.

The cathode of X-ray tube 25 likewise receives heating current through a pair of conductors 38 and 39 from a suitable source of low-tension energy, such as a transformer 40, with the primary thereof also connected to the commercial source L1, L2, and a condenser 42 is connected in a shunt circuit with the secondary winding of this transformer 40 and the cathode of the X-ray tube.

It can thus be appreciated that when the discharge device 29 is operated, which as before stated constitutes a switch, the condensers 16 and 18 immediately discharge and energize the X-ray tube. It should perhaps be here noted that prior to operation of the discharge device 29 to cause discharge of these condensers the aforementioned switch (not shown), which connects the primary winding 6 of high tension transformer 5 to the alternating current source L1, L2, is opened to interrupt the charging circuit for these condensers. This accordingly divorces the condensers 16 and 18 from the alternating current source in order to prevent the same from influencing the wave of the condenser discharge energy by superimposing a sinusoidal ripple thereupon as obvious from the curves shown in Figs. 2 and 3 and as more fully detailed in my above referred to copending application Serial No. 582,833.

This discharge circuit may be traced from condenser 16 through conductor 26, X-ray tube 25, through conductors 38 and 39, resistance element 31, conductor 30 to anode of discharge device 29, and from the cathode thereof through conductors 32 and 33, resistance element 28, and thence through conductor 27 back to condenser 18 which is connected in series with condenser 16 and the X-ray tube 25. High potential energy will accordingly be supplied to the X-ray tube during the time the discharge device or switch 29 is in the "closed" position.

In the absence of the resistance elements 28, 31 and condensers 37, 42 a potential from the source or condensers 16 and 18 would be impressed upon the X-ray tube in the normal manner of condenser discharge, i. e., it will suddenly rise from zero to maximum and gradually taper off again to zero with an entire absence of a sinusoidal ripple therein due to their divorcement from the alternating current source L1, L2 as the energy of the condensers is dissipated as shown by the curve "A" of Fig. 2. Accordingly the current flowing through the X-ray tube will likewise suddenly rise and taper off to zero substantially as shown by the curve "B" in this figure wherein there is likewise an absence of a sinusoidal ripple.

This sudden rush of current may have a deleterious effect upon the X-ray tube by puncturing the glass envelope or disruption of its thermionic cathode. Moreover, the energy supplied to the X-ray tube is converted into X-rays having an energy-wave length distribution over the period of energization of the tube simulating that of the discharge of the condensers. In other words the energy-wave length distribution of the X-rays generated will be approximately as graphically expressed by the curve "C" of Figure 2 which simulates the voltage and current curves "A" and "B", respectively, in that there is a sudden generation of X-rays of great penetrative power which taper off to soft X-rays of lesser penetrative power.

To prevent any deleterious effects to the X-ray tube and discharge device 29 I provide the resistance element 28 and condenser 37 in a shunt circuit with the cathode of the device 29, and similarly the resistance element 31 and condenser 42 in shunt with the cathode of the X-ray tube. Upon the initial surge of the current supplied by the condensers to the X-ray tube a slight IR drop occurs in the respective elements 28 and 31, with a portion of this surge being absorbed by the condensers 37 and 42 taking part of this energy. After these condensers have taken their respective charge they then discharge into the high voltage system as shown and claimed in my copending application Serial No. 601,071, filed March 25, 1932.

This action of the resistance elements together with the condensers 37 and 42 accordingly reduces the steepness of the wave front of the energy supplied to the X-ray tube by the high tension condensers 16 and 18. Accordingly the initial surge from zero to maximum discharge of the voltage and current supplied by these condensers is made more gradual in the manner as shown by the initial rise or "front" of voltage and current curves "A" and "B" respectively of Figure 3, thus obviating the possibility of the sudden rush of current disrupting the cathode or puncturing the envelope of the X-ray tube 25 or discharge device 29.

For the purpose of operating the discharge device 29 as a switch I provide the same with a control electrode, such as a grid, interposed between the anode and cathode thereof. A suitable auxiliary source of energy is arranged, under one condition of operation to impress a negative potential upon this grid to prevent the flow of electrons between the cathode and anode of the

device 29 and consequently from the condensers 16 and 18 to the X-ray tube 25 which is the "open" position of the switch. Under the other, or switch "closed" position a positive potential is impressed upon the grid by the auxiliary source thus causing electron flow between the cathode and anode of the device 29 with attendant discharge of the condensers 16 and 18 through the X-ray tube.

This auxiliary source must impress a negative potential upon the grid of the controlling discharge device of sufficient magnitude to prevent discharge of condensers 16 and 18 which it must be appreciated are stored with energy at a potential of from 75 to 100 kilovolts.

Likewise, when the device is operated to cause energization of the X-ray tube, or switch "closed" position, the magnitude of the positive potential must be comparatively high, although not as high as when a negative potential is impressed on the grid in the switch "open" position.

For example, the negative potential impressed upon the grid must be of a magnitude of between 5,000 and 10,000 volts while the positive potential need be only between 750 and 1000 volts. Moreover, I have found it is essential that the polarity of the potential impressed upon the grid must be reversed without opening of the circuit from the auxiliary source. If this is not done, but the circuit opened to remove the negative potential thus allowing the potential to fall to zero and then closed to impress a positive potential upon the grid, the high potential energy stored in the condensers 16 and 18 will immediately start to discharge. This immediately causes the grid to assume a negative polarity which again functions to block the flow of electrons from the cathode to the anode of the device 29 before the application of a positive potential thereto thus resulting in an interruption to the discharge of the condensers through the X-ray tube for an appreciable fraction of a second. Accordingly by not opening the circuit from the auxiliary source the change in polarity from negative to positive occurs substantially instantaneously without interfering in any way with discharge of the high tension condensers and energization of the X-ray tube.

I have also found that it is sometimes highly desirable to produce X-rays of desired characteristics, i. e., having a predetermined energy-wave length distribution during the period of generation thereof.

In accordance with my present invention I produce these X-rays by causing the potential impressed upon the X-ray tube to have a predetermined wave form which in turn causes the generation of X-rays of predetermined characteristics. By not only utilizing the grid of the device 29 as a control electrode, but in also modulating the potential impressed thereupon I cause the potential impressed upon the X-ray tube by the condensers 16 and 18 to likewise be modulated and obtain a predetermined wave form simulating that of the modulated grid potential.

The auxiliary source of potential may comprise a circuit similar to that of the high potential circuit, namely, a transformer 52, having its primary winding 53 connected to the commercial source of potential L1, L2. The secondary winding 54 of this transformer has one of its ends connected to the anode of a rectifying valve 55 and its other end connected to the cathode of a similar rectifying valve 56. The cathode terminal of rectifying valve 55 is connected, by means of a conductor 57, to a condenser 58 with the anode terminal of the rectifying valve 56 connected by means of a conductor 59 to a condenser 60 of larger capacity than that of condenser 58. A conductor 62 interconnects the condensers 58 and 60 and is in turn connected, by a conductor 63, to a point of the secondary winding 54 disposed nearer one end thereof than the other.

The cathodes of the respective valve tubes 55, 56 receive heating current through conductors 64 and 65 from a suitable source of energy, such as a low-tension transformer 66, the primary winding of which may be connected to the commercial source L1, L2.

This portion of the auxiliary source is arranged to store energy during each half wave of the alternating current cycle in the respective condensers 58 and 60 which are arranged to discharge through an output circuit connected to the conductors 57 and 59 and thus to the positive and negative terminals, respectively, of the condensers 58, 60. A conductor 67 extends from the positive terminal of the condenser 58 to the cathode of the discharge device or switch 29 while a similar conductor 68 connects the negative terminal of the condenser 60, through a high resistance 69, to the control electrode or grid. With the auxiliary source thus connected, upon energization of the transformer 52, energy will be first supplied to the condensers 58, 60, which will then discharge cyclically into the output circuit. A high negative potential will accordingly be impressed through the high resistance element 69 to the grid of switch 29, due to condenser 60 being of a larger capacity than condenser 58, which is energized by the greater portion of secondary winding 54, while a positive potential of lesser magnitude is impressed upon the cathode thereof by the condenser 58.

The grid being highly negative with respect to the cathode, which is impressed with a positive potential, as just stated, prevents the flow of electrons from the latter to the anode thus completely blocking the discharge of the high tension condensers 16 and 18, and energization of the X-ray tube. In order to reverse the polarity of the potential impressed by the auxiliary source upon the grid of the control tube 29 I provide a remotely controlled switch operating mechanism, indicated by this legend in Figure 1, which is adapted to establish a contact with two switch terminals 72 and 73.

The switch terminal 73 is connected by means of a conductor 74 to the conductor 68 between the high resistance element 69 and the grid of the switching device 29, and the switch terminal 72 is connected, through a generator of predetermined wave form to be more fully hereinafter explained, to the conductor 67. Upon actuation of the switch operating mechanism by an operator, following opening of the switch in the source of supply for the primary winding 6 as before stated, a connection is established between the switch terminals 72 and 73 which reverses the polarity impressed upon the grid of the device 29 from its previous negative potential to a positive potential without interrupting the circuit from the auxiliary source, as more fully set forth in my aforementioned copending application Serial No. 582,933.

At the same time the grid is made positive the cathode is made negative with respect to the grid, with the result that the high tension energy stored in the condensers 16 and 18 discharges and energizes the X-ray tube simultaneously with

the reversal of the polarity of the grid. The potential impressed upon the X-ray tube would accordingly be as graphically expressed by the curve "A" and the current flowing therethrough as that of curve "B" in Figure 3 upon discharge of the condensers 16 and 18. The positive potential impressed upon the grid by the auxiliary source upon the reversal of polarity, in the absence of my generator of predetermined wave form, would be as expressed by the curve "D" in Figure 2, wherein the potential rises abruptly to maximum after which it remains substantially uniform throughout the period of energization of the X-ray tube.

The current in flowing through the X-ray tube in the manner shown by the curve "B" in Figure 2 will, as previously stated, cause the generation of X-rays having an energy-wave length distribution substantially identical with that expressed by the curve "C". In order, however, to produce X-rays having substantially any desired characteristics I modulate the grid potential by impressing thereupon a potential having a predetermined wave form corresponding to that required to generate X-rays of the desired characteristics.

Accordingly the switch operating mechanism is connected to a suitable generator of predetermined wave form, as shown in Figure 1, for the purpose of impressing a potential having the wave form selected by this generator upon the grid of the device 29 simultaneously with the operation of the switching mechanism to cause reversal of the polarity of the grid potential. This generator may be of any particular design, such for example as an alternating current generator, connected to a bank of batteries, a tube oscillating generator, or a bank of batteries connected to a potentiometer the movable contactor of which may be driven by a suitable motor, for producing the desired wave form. Any preselected wave form for the grid potential, which may be for example in the form shown by the curve "D" in Figure 3, when impressed upon the grid simultaneously with its reversal from negative to positive, will accordingly cause a variation in the potential impressed upon the X-ray tube in the manner as shown by curve "A" of Figure 3. Likewise a variation simultaneously occurs in the discharge current and resultant X-ray energy-wave length distribution as shown by the curves "B" and "C", respectively.

By varying the form of the energy supplied to the X-ray tube by the high potential source in this manner, during energization of the X-ray tube, X-rays having desired preselected characteristics or energy-wave length distribution are generated corresponding to variations in the wave form of the potential generated by the predetermined wave form generator. When X-rays of a predetermined characteristic are desired, it is only necessary to set the generator of predetermined wave form to the particular wave form required to produce this type of X-rays and simultaneously with reversal of the polarity of the grid the generator modulates the latter to effect the high potential energy.

It can thus be readily seen by those skilled in the art that I have produced an X-ray system in which the potential impressed upon the X-ray tube is given a predetermined wave form in order to cause a variation in the discharge current with a resultant generation of X-rays having desired energy-wave length distribution. When a specific wave form of applied X-ray voltage for any particular radiographic purpose has been determined either empirically or otherwise as giving the best results it is only necessary to set the generator of predetermined wave form for a particular wave form and this specific wave form of applied X-ray voltage results with all subsequent exposures identical in the character of X-rays produced.

Having thus described my invention it is apparent that other changes and modifications may be made therein without departing from the spirit and scope of the invention as set forth in the appended claims.

What is claimed:

1. The method of producing X-rays of predetermined characteristics in a circuit including an X-ray tube and a source of high potential rectified alternating current energy entirely free of sinusoidal modulation, which consists in modulating the wave form of the potential of the original source in a preselected manner and applying this modulated high potential across the terminals of the X-ray tube.

2. The method of producing X-rays of predetermined characteristics in a circuit including an X-ray tube and a source of high potential rectified alternating current energy of suddenly increasing and gradually diminishing magnitude for energizing the X-ray tube, which consists in modulating the wave form of the potential of the high potential energy by a potential from an auxiliary source entirely independent of the high potential source and having a preselected wave form, and applying this modulated high potential to the X-ray tube.

3. The method of producing X-rays of predetermined characteristics in a circuit including an X-ray tube and a source of high potential rectified alternating current energy of suddenly increasing and gradually diminishing magnitude for energizing the X-ray tube, which consists in modulating the wave form of the potential of said original source of energy by a potential from an auxiliary source entirely independent of said original source and having a preselected wave form, and causing a predetermined wave form in the discharge current flowing through the X-ray tube with an attendant generation of X-rays having predetermined distribution characteristics which correspond substantially to that of the predetermined wave form of the discharge current.

4. The method of producing X-rays of predetermined characteristics in a circuit including an energy storage device energizable from a suitable source of high potential rectified alternating current energy, and an X-ray tube energizable by said energy storage device, which consists in accumulating a charge of high potential electrical energy in the energy storage device from said high potential source, suddenly energizing the X-ray tube by the charge accumulated in the energy storage device, and modulating the wave form of the potential impressed upon said X-ray tube by an auxiliary source of potential independent of the high potential source and having a preselected wave form.

5. The method of producing X-rays of predetermined characteristics when employing an X-ray tube in series with a three electrode tube provided with a control electrode, and a source of high potential rectified alternating current energy of suddenly increasing and gradually diminishing magnitude for energizing the X-ray tube, which consists in impressing a suitable potential

upon the control electrode of said three electrode tube to cause energization of said X-ray tube, and modulating the potential impressed upon the control electrode in a preselected manner to cause the wave form of the potential impressed upon the X-ray tube by the high potential rectified source to be of a characteristic which is different from the potential of said high potential source at its origin.

6. The method of producing X-rays of predetermined characteristics when employing an X-ray tube in series with a three electrode tube provided with a control electrode, and a source of high potential rectified alternating current energy entirely free of sinusoidal influence from the alternating current, which consists in impressing a potential of a predetermined wave form upon the control electrode of said three electrode tube from an auxiliary source of electrical potential independent of said high potential source, to cause the sudden energization of the X-ray tube and the potential impressed upon the X-ray tube by the high potential rectified source to be modulated by the potential of said auxiliary source, and causing the X-ray tube to generate X-rays of preselected characteristics simulating the wave form of the modulated potential impressed upon the X-ray tube.

7. The method of producing X-rays of predetermined characteristics by employing a circuit including a source of high potential rectified alternating current energy of suddenly increasing and gradually diminishing magnitude for energizing an X-ray tube, and an electron discharge device having a control electrode, which comprises impressing a negative potential upon the control electrode of the electron discharge device from an auxiliary source to prevent energization of the X-ray tube by the high potential rectified source, reversing the polarity of the potential of the auxiliary source to cause the sudden energization of the X-ray tube by the high potential source, and simultaneously modulating the potential impressed upon the control electrode in a preselected manner, to cause the potential impressed upon the X-ray tube by the high potential rectified source to have a preselected wave form and produce X-rays of preselected characteristics which are determinable by the wave form of the potential impressed upon the X-ray tube.

8. In an X-ray system for producing X-rays of predetermined characteristics, the combination of a source of high potential electrical energy including a high tension transformer and a condenser, an X-ray tube energizable by said source, and means independent of said source and connected thereto and to said X-ray tube and operable to modulate the potential impressed upon said X-ray tube in a preselected manner, to cause said X-ray tube to generate X-rays having preselected characteristics determinable by the modulated potential impressed upon said X-ray tube.

9. In an X-ray system for producing X-rays of predetermined characteristics, the combination of a source of high potential rectified alternating current electrical energy, an X-ray tube energizable by said source, and means interposed between said source and said X-ray tube and operable to cause and prevent the energization of said X-ray tube by said high potential source, said means when operated to cause energization of said X-ray tube being also operable to simultaneously modulate the potential impressed upon said X-ray tube in a preselected manner to cause said X-ray tube to generate X-rays having preselected characteristics determinable by the modulated potential.

10. In an X-ray system for producing X-rays of predetermined characteristics, the combination of a source of high potential rectified alternating current electrical energy, an X-ray tube energizable by said source, means connected to said source and to said X-ray tube and operable to control the energization of said X-ray tube by said source, and means connected to said first mentioned means and operable to render the same effective to cause and prevent the energization of said X-ray tube, and for simultaneously causing said first mentioned means to modulate the potential impressed upon said X-ray tube in a preselected manner to produce X-rays having predetermined characteristics which are determinable by said last mentioned means.

11. In an X-ray system for producing X-rays of predetermined characteristics, the combination of a source of high potential rectified alternating current electrical energy free from sinusoidal influence by the alternating current, an X-ray tube energizable by said source, an auxiliary source of electrical energy independent of said high potential source and having a potential of a preselected wave form, and means connected to said X-ray tube and to said high potential and auxiliary sources, and operable to cause the potential impressed upon said X-ray tube by said high potential source to be modified by the preselected wave form of the potential of said auxiliary source, and cause said X-ray tube to generate X-rays having preselected characteristics determinable by the preselected wave form of the potential of said auxiliary source.

12. In an X-ray system for producing X-rays of predetermined characteristics, the combination of a source of high potential rectified alternating current electrical energy of suddenly increasing and gradually diminishing magnitude, an X-ray tube energizable by said source, a three electrode discharge device having a control electrode and connected in series with said high potential source and said X-ray tube, an auxiliary source of potential connected to the control electrode of said discharge device operable to render the latter effective to cause and prevent the energization of said X-ray tube by said high potential source, and means associated with said auxiliary source and operable to simultaneously impress a potential having a preselected wave form upon the control electrode of said discharge device, to cause a modulation of the potential impressed upon said X-ray tube by said high potential source with a resultant generation of X-rays having preselected characteristics determinable by the wave form of the potential impressed upon said control electrode by said auxiliary source.

13. In an X-ray system for producing X-rays of predetermined characteristics, the combination of an X-ray tube, a source of high potential electrical energy for energizing said X-ray tube, a thermionic discharge device provided with a control electrode and connected to said source and said X-ray tube, and operable to control the energization of said X-ray tube, an auxiliary source of potential connected to the control electrode of said discharge device for normally impressing a negative potential thereupon to render said discharge device effective to prevent energization of said X-ray tube by said high potential source, a switch associated with said auxil-

iary source and operable to cause the same to impress a positive potential upon the control electrode of said discharge device to render the latter operative to cause energization of said X-ray tube, and a source of electrical potential having a predetermined wave form adapted to be simultaneously connected to the control electrode of said discharge device upon operation of said switch to cause modulation of the positive potential impressed thereupon with attendant modulation of the potential impressed upon said X-ray tube by said high potential source thereby causing the generation of X-rays of a predetermined characteristic dependent upon the modulation of the source having a predetermined wave form.

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